DEPARTMENT OF THE INTERIOR

CANADA

HON. W. J. ROCHE, *Minister.* W. W. CORY, C.M.G., *Deputy Minister.*

PUBLICATIONS

OF THE

Dominion Observatory

OTTAWA

W. F. KING, C.M.G., LL.D., *Director.*

Vol. II, No. 10

Gravity

BY

F. A. McDIARMID, B.A.

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GRAVITY.

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GRAVITY.

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INTRODUCTION.

Canada is largely a new field for gravity observations; of the immense country from the Atlantic to the Pacific, and from the southern boundary to the Arctic ocean, there have been gravity determinations made at only four points. Dr. Otto Klotz, under whose supervision the work is at present carried on, made observations at Ottawa, Toronto and Montreal in 1902; and Professor L. B. Stewart observed at Northwest River, Labrador, in 1905. Reasons for the prosecution of a gravity campaign covering the whole country will be given later in this report, and also a comparison of the results obtained for Ottawa by Dr. Klotz with those obtained last season will be shown.

The following report of the gravity observations made at eighteen stations during the past season is considered under the following heads:—

Position and description of stations.
Instruments and apparatus.
Use of apparatus.
Method of observation.
Determination of coefficients.
Rating of chronometers.
Reduction of observations.
Changes in lengths of pendulums.
Periods of pendulums.
Deduction of absolute gravity.
Computation of the intensity of gravity at any selected station.
Corrections for elevation, topography, and isostatic compensation.
Reasons for the prosecution of pendulum work.
Conclusion.

POSITION AND DESCRIPTION OF STATIONS.

The gravity stations occupied during the summer of 1914 are in the provinces of Ontario and Quebec; in Ontario—Ottawa, Kingston, Mattawa, Liskeard, Cochrane, Sault Ste. Marie, Chapleau, Port Arthur, Rose Point, Whitby, Woodstock and Windsor; in Quebec—Maniwaki, Roberval, Tadoussac, Portneuf, St. Jérôme and Ste. Anne-de-Bellevue.

For the purpose of standardizing the pendulums, observations were made at Washington. The pendulum pier in the basement of the Coast and Geodetic Survey building is the base of all the gravity observations in the United States. The observed value of gravity at Washington (C. & G. S.) is 980·112 dynes. This value depends upon the absolute determination of the value of gravity at Potsdam, Germany, and upon the relative values at Potsdam and Washington, as determined by Mr. G. R. Putman in 1900.

Ottawa will be used as the base for all the Canadian work, and as the gravity at Ottawa has been determined differentially from Washington, all the gravity determinations on the North American continent will depend on the value at Washington, and as Washington was determined from Europe, there is a common base for all gravity results.

Early in March of the year 1914, the writer was directed to proceed to Washington with the pendulum outfit. The apparatus had not been used for a number of years, and needed a complete overhauling. The pendulums were constructed some years ago under the supervision of Mr. E. G. Fischer, Chief of the Instrument Division of the Coast and Geodetic Survey; and Mr. Fischer very kindly placed the whole outfit in good order. The writer, here, wishes to express his gratitude to Mr. Tittmann, Superintendent of the Coast and Geodetic Survey, for giving every facility for the furtherance of the work. Mr. William Bowie, Chief of the Computing Division and Inspector of Geodetic Work, gave much valuable information concerning gravity observations, and also on other lines of geodetic work. In the observing, Mr. C. H. Swick of the Computing Division assisted; Mr. Swick has had considerable field experience, and was most painstaking in giving every aid possible.

After determining the periods of the three pendulums 1, 2 and 3 in Washington the instruments were shipped to Ottawa, and the periods determined. The trip Ottawa to Washington to Ottawa was repeated, and second sets of observations were made both at Washington and Ottawa. These four sets, two at Washington and two at Ottawa, give two independent determinations of the gravity at Ottawa, and establish Ottawa as a base point for all Canadian work.

The pendulum stations established during the summer of 1914 were all located near astronomical stations, and are described as follows:—

Ottawa.—The pendulum pier was in the southwest corner of the basement of the Dominion Observatory.

Maniwaki.—The pendulum pier was in the cellar of the Larentier hotel, 4 feet below the level of the rail in front of the C.P.R. station, and 120 feet due west of the astronomical station (1906), distance to astronomical station measured.

Kingston.—The pendulum pier was in the furnace room of the city hall, 10 feet below the G.S.C. bench-mark in the Kingston post office, and 2700 feet west and 950 feet south of the astronomical station (1905) on the Royal Military College grounds, distance to astronomical station scaled from map of the city of Kingston.

Roberval.—The pendulum pier was in the cellar of Mr. Legault's residence, 2 feet below the level of the rail in front of the Quebec and Lake St. John railway station, and 935 feet south and 570 feet east of the astronomical station (1907), distance to astronomical station measured.

Tadoussac.—The pendulum pier was in the cellar of the Tadoussac hotel, 40 feet above mean tide water, and 190 feet south and 60 feet west of the astronomical station (1905), distance to astronomical station measured.

Portneuf.—The pendulum pier was in the foundry near the C.P.R. station, the same elevation as the rail in front of the station, and 135 feet south and 570 feet west of astronomical station (1903), distance to astronomical station measured.

St. Jérôme.—The pendulum pier was in the cellar of the Chateau Larose, 7 feet below the level of the rail in front of the C.P.R. station, and 42 feet north and 472 feet west of astronomical station (1908), distance to astronomical station measured.

Ste. Anne-de-Bellevue.—The pendulum pier was in the basement of the Physics building, Macdonald college, 10 feet below the level of the rail in front of the G.T.R. station, and 1949 feet east and 122 feet north of the astronomical station (1905), distance to astronomical station scaled from map of the town of Ste. Anne-de-Bellevue.

Mattawa.—The pendulum pier was in the cellar of the Victoria hotel, 10 feet below the level of rail in front of the C. P. R. station, and 210 feet north and 300 feet east of astronomical station (1907), distance to astronomical station measured.

Liskeard.—The pendulum pier was in the basement of the public library, 7 feet below the level of rail in front of the T. & N. O. railway station, and 4090 feet east of astronomical station (1906), distance to astronomical station scaled from plan of Liskeard.

Cochrane.—The pendulum pier was in the cellar of the King George hotel, on level with rail in front of the T. & N. O. railway station, and 1700 feet east and 20 feet north of astronomical station (1909), distance to the astronomical station scaled from map of the town of Cochrane.

Sault Ste. Marie.—The pendulum pier was in the furnace room of the city hall, 22 feet below the level of rail in front of the C. P. R. station, and 508 feet south and 700 feet east of astronomical station (1910), distance to astronomical station scaled from map of the town of Sault Ste. Marie.

Chapleau.—The pendulum pier was in the cellar of V. J. Perpeté's store near the C. P. R. station, 6 feet below the level of the rail in front of the C. P. R. station, and 860 feet east and 510 feet south of astronomical station (1907), distance to astronomical station scaled from map of town of Chapleau.

Port Arthur.—The pendulum pier was in the cellar under the Masonic building, Arthur street, 12 feet above the level of the rail in front of the C. P. R. station, and 1148 feet west and 546 feet north of astronomical station (1887), distance to astronomical station scaled from map of the city of Port Arthur.

Rose Point.—The pendulum pier was in the cellar of the Rose Point hotel, 2 feet below the level of rail in front of the G. T. R. station, 150 feet west and

100 feet north of astronomical station (1900), distance to astronomical station measured.

Whitby.—The pendulum pier was in the cellar of E. R. Blow's store, 8 feet above the level of rail in front of G. T. R. station, 50 feet south and 300 feet west of astronomical station (1905), distance to astronomical station measured.

Woodstock.—The pendulum pier was in the basement of the market building, 10 feet below the G. S. C. bench-mark in the Woodstock post office, 3800 feet west and 2500 feet north of the astronomical station (1903), distance to astronomical station scaled from map of the city of Woodstock.

Windsor.—The pendulum pier was in the cellar under the C. P. R. telegraph office, 14 feet below the G. S. C. bench-mark in the Windsor post office, 780 feet north and 1490 feet east of the astronomical station (1910), distance to astronomical station scaled from map of the city of Windsor.

These stations were previously occupied for longitude and latitude, so their geographical positions are accurately known. The figures for elevation were obtained from the best information available. Whenever possible the bench-marks of the Geodetic Survey of Canada were tied to, and for all other stations the figures for altitude as given by White's "Altitudes in Canada" were used.

In the following table are given brief descriptions of the pendulum piers, the longitude, the latitude, and the altitude of each station. At every station with the exception of Portneuf a dry cellar with a good concrete floor was found, and a pier constructed by cementing three cubical stones of equal height to the concrete floor with plaster of Paris. The pendulum case (receiver) was then placed on the pier. This method of mounting proved very satisfactory. At Portneuf a concrete floor in a foundry was used as the observing station, and on account of the frequent changes of temperature it was necessary to take thermometer readings every few hours. With the exception of Portneuf, at no station was there a larger range of temperature than three degrees Centigrade during the two days of observing.

Station.	Longitude.			Latitude.			Altitude.	Description of Station
	h.	m.	s.	°	′	″	metres	
Washington	5	08	09	38	53	13	.....	Pendulum pier in basement of C. & G. S. building.
Ottawa	5	02	52	45	23	39	83	Pendulum room in basement of Dominion Observatory.
Maniwaki	5	03	55	46	22	28	169	Concrete floor in cellar of Larentier hotel.
Kingston	5	05	52	44	13	37	79	Concrete floor in furnace room of city hall.
Roberval	4	48	54	48	30	54	107	Concrete floor in cellar of residence of Mr. Legault
Tadoussac	4	38	52	48	08	25	12	Concrete wall around furnace in cellar of Tadoussac hotel.
Portneuf	4	47	35	46	42	32	59	Concrete floor in foundry near C.P.R. station.
St. Jérôme	4	52	28	45	46	34	107	Concrete floor in basement of Chateau Larose.
Ste. Anne-de-Bellevue	4	55	48	45	24	27	34	Concrete floor in basement of Physics building, Macdonald College
Mattawa	5	14	47	46	18	43	170	Concrete floor in basement of Victoria hotel.
Liskeard	5	18	50	47	30	34	194	Concrete floor in basement of public library.
Cochrane	5	24	05	49	03	44	277	Concrete floor in basement of King George hotel.
Sault Ste. Marie	5	37	18	46	30	26	186	Concrete floor in basement of city hall.
Chapleau	5	33	36	47	50	27	430	Concrete floor in cellar of V. J. Perpeté's store
Port Arthur	5	56	52	48	26	08	189	Concrete floor in basement of Masonic building.
Rose Point	5	20	10	45	19	02	183	Concrete floor in basement of Rose Point hotel.
Whitby	5	15	46	43	52	43	84	Concrete floor in cellar of E. R. Blow's store.
Woodstock	5	23	07	43	08	33	288	Concrete floor in basement of market building.
Windsor	5	32	10	42	19	06	178	Concrete floor in basement of C.P.R. telegraph office.

INSTRUMENTS AND APPARATUS.

The outfit used in all the work consisted of half-seconds pendulums 1, 2 and 3 with the accompanying air-tight receiver, flash apparatus, wherein an electro-magnet in the circuit of a chronometer moves a shutter and throws a flash of light every two seconds, a telescope for observing, mounted above the flash apparatus, dummy or temperature pendulum, sidereal break-circuit chronometers Bond 519 and Dent 52866, thermometers, air pump, dry cells, chronograph, switchboard and flash lamp. When necessary to determine time by star observations a transit telescope must be added, but this year time signals were sent from the standard sidereal clocks at the Dominion Observatory, and a transit was not needed.

The receiver and pendulums are described in the "Report of the Chief Astronomer, 1905, Appendix 2"; the flash apparatus is also described in that report, but in order to explain the mechanism of the shutter the whole flash apparatus will be briefly described.

*Flash apparatus**.—The flash apparatus consists of a light metal box, mounted on a brass stand having both vertical and azimuthal movements and clamps, and carries with it an ordinary observing telescope, *e*, which may be focussed for objects within a few feet. The object of the flash apparatus is to observe coincidences between the swinging pendulum and the chronometer used for determining the period or time of an oscillation of the pendulum, which in turn depends upon the time determination made by means of the chronometer, *i.e.*, the time determination made by observing transits of stars with the chronometer as a scale with which to measure the period of the pendulum. This box contains an electro-magnet, whose coils are connected with the chronometer circuit, and whose armature carries an arm which moves two shutters, and by an ingenious device a flash of light is emitted from the box when the circuit is broken, but not when it is closed.

The apparatus is shown in the accompanying diagram (Fig. 1), and with one side of the box removed. This box contains an electro-magnet, *a*, whose coils are connected to the chronometer circuit through the binding posts, *f*, projecting through an opening in the end of the box. This arm carries two shutters, *t* and *v*, by means of which a flash of light is emitted from the box when the circuit is opened, but not when closed. In the front of the box are placed two pieces of metal, *z*, leaving a narrow horizontal slit between them, and behind them move the two shutters, *t* and *v*. The arm, *d*, passes through the upper end of these two shutters; *t* has no play on the arm, but moves directly with it; the opening in *v*, however, is somewhat longer than the thickness of the arm, so that it does not move until the arm is near the middle of its stroke. A stop prevents the slit in *v* from descending below that in *z*, and a friction spring, *h*, holds *v* so that it moves only with the arm. When the circuit is closed the arm, *d*, is down and the slit, *t*, is below the line of slits, *v* and *z*. As soon as the circuit is broken the spring, *h*, causes the arm to rise and the slit, *t*, passes the line of slits, *v* and *z*, emitting a flash of light. Before the end of the stroke, the arm also lifts the shutter, *v*, so that its slit is no longer in line with the slit in *z*. When the circuit is again closed the arm, *d*, is pulled down, but the slit in *t* is opposite that in *z* when *v* just commences to move, so that the three slits are not in line, and no flash

* United States C. & G. S. Report, 1891, Appendix 15.

is emitted. It is thus seen that the three slits are only in line immediately after the breaking of the circuit. A small oil lamp attached to one side of the box furnishes the light for the flash, the light being concentrated by a lens on the slit after being reflected by a mirror in the interior of the box set at an angle of 45°. The tension on the friction spring must not be changed during a set of pendulum readings, otherwise the slits would not have the same relative motion to one another.

When the pendulum is swinging, the image as reflected from the pendulum mirror will change its position relatively to that of the fixed mirror as seen in the field of the telescope, because of the fact that the pendulum makes a double oscillation in a little more than a sidereal second, and will be found a little behind its former position at the end of each break when the flash is thrown. The moving image will, therefore, appear to travel up and down the field of the telescope by successive jumps, wholly disappearing from the field to return again with apparent retrograde motion. Coincidences are observed by noting the time when the two images are in the same horizontal line. It is evident that in the interval between two occurrences of this phenomenon, the pendulum has made one less than twice as many oscillations as the chronometer has beat seconds, and that in the mean interval of time between the first and last of a number of coincidences, the number of oscillations of the pendulum will be twice the number of seconds (s) less the number of coincidence intervals (n), so that the time of a single oscillation is readily derived from the relation $P=\frac{s}{2s-n}$. The beauty of the coincidence method lies in the fact that a small error in noting the time of a coincidence has little effect on P.

Chronometers.—Two chronometers are used in the observation of coincidences. One serves as a check on the other, and seldom does the period of an oscillation, as determined from the two, differ by more than one or two in the seventh decimal place of the period of the pendulum. The chronometers used during the season of 1914 are Bond No. 519 and Dent No. 52866. During a part of the observations at Ottawa the Negus chronometer No. 2088 was also used.

Thermometers.—The thermometers in the pendulum outfit are Green Nos. 116, 118 and 121. No. 118 was used at Washington, Ottawa, Maniwaki and

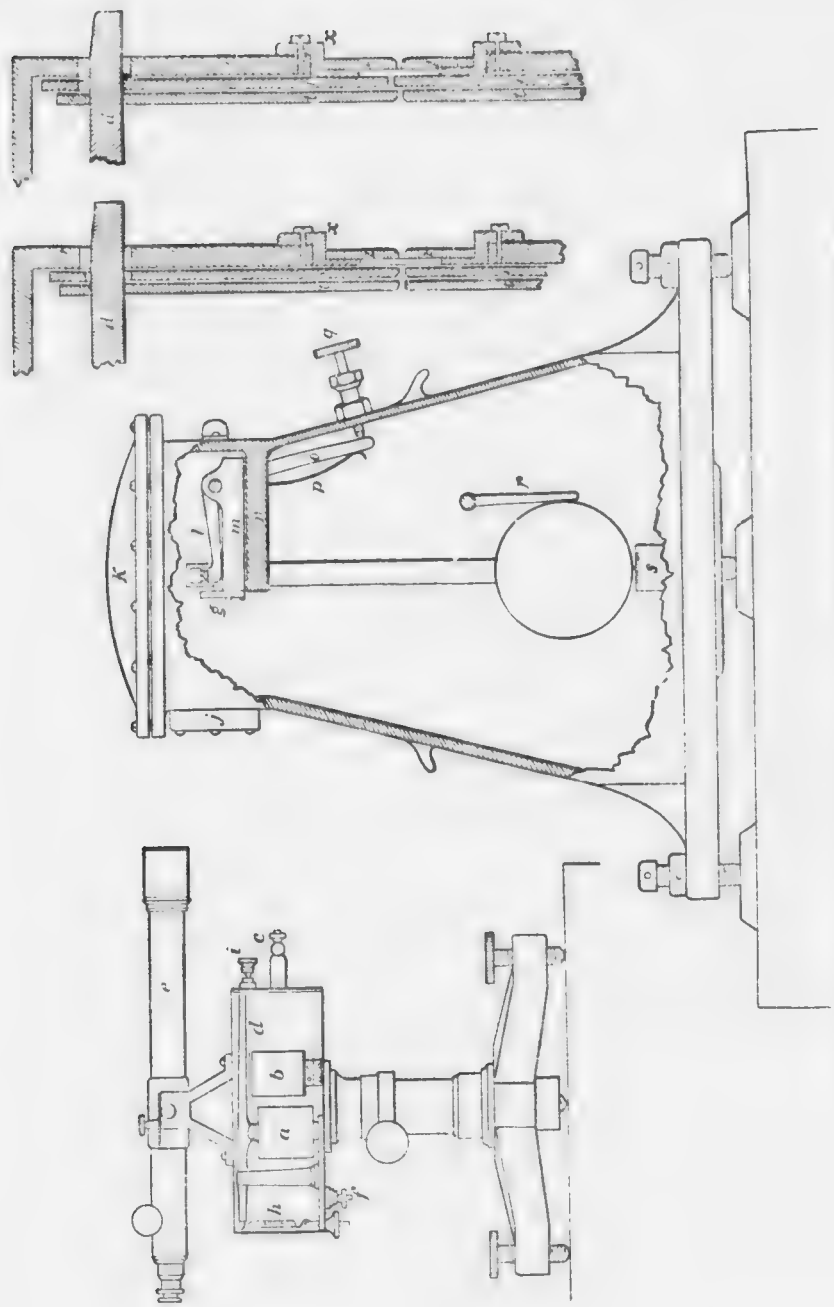


FIG. 1.—SIDE ELEVATION OF RECEIVER AND FLASH APPARATUS AND SECTION THROUGH SHUTTERS.

Kingston, and No. 121 at all the other stations. The thermometers were standardized at the Bureau of Standards in Washington, and the corrections are in the following table:—

Thermometer reading.	Correction.		
	No. 116.	No. 118.	No. 121
	°	°	°
0° C.	− 0 10	− 0 10	− 0 10
10 C.	− 0 15	− 0 10	− 0 00
20 C.	− 0 20	− 0 15	− 0 05
30 C.	− 0 25	− 0 15	− 0 05

When the sign is + the correction should be added to, and when − subtracted from the observed reading.

Chronograph.—A Fauth (Saegmüller) chronograph was used for comparing the two chronometers, and also for receiving time signals from Ottawa.

Switchboard.—The switchboard is one that has been used in longitude work. It is so arranged that the chronometer beats can be transmitted over the telegraph line, and also recorded on the chronograph sheet. Two additional switches were mounted on the board for using the chronometer relay either in the chronograph circuit, or in the circuit with the flash apparatus.

USE OF APPARATUS.

Very little preparation was needed at a station before mounting the instrument. A cellar with a concrete floor was generally easily found, and as stated above, three cubical stones of equal thickness were secured, and made fast to the floor with plaster of Paris. The stones were needed to raise the receiver to a sufficient height to enable the flash apparatus to be mounted in a position suitable for observing. In some places the floor was so constructed that the receiver could be mounted on the floor directly. The different boxes in which the outfit was packed were used as tables, etc. The chronometers were always kept in their padded carrying boxes, so as to preserve as nearly as possible the same temperature. As pointed out above, the change of temperature rarely

exceeded two degrees Centigrade during the two days spent at a station. Before commencing observations, the pendulum case and the pendulum should be mounted in the observing room for several hours, in order that the pendulum and case will both be at the temperature of the room. If the temperature of the room is constant, thermometer readings at the beginning and end of a swing will be sufficient; and even if the temperature is changing gradually, two readings will suffice. However, if the temperature is fluctuating, then the thermometer must be read frequently. In order to keep the temperature constant it is well to close all windows and doors. Black cotton is used for darkening windows and cutting off extraneous light

METHOD OF OBSERVATION.

After selecting and preparing the station, the receiver is placed in position and levelled, and the relation between the agate planes and the exterior level is determined by means of the small pendulum level. The dummy pendulum and the manometer are then put in position. One of the pendulums is placed in the chamber on the lifter, that it may come to the temperature of the air. The flash apparatus is placed in position and after finding the images of the slit on the mirrors, the stationary mirror is adjusted so as to make the two images lie in the same straight line and slightly overlap. The surfaces of the top of the receiver and the cap having been thoroughly cleaned, a little lard or soft tallow is rubbed evenly over them, and the cap is placed in position. By moving the cap from side to side under considerable pressure from the hands, good contact is generally secured without difficulty.

The air-pump is then attached and the air exhausted to about 50 millimetres. After exhausting the chamber some time should elapse before commencing observations, in order to insure that the pendulum reaches the temperature of the receiver.

After having obtained the errors of the sidereal chronometers, either by comparison with some standard clock or from star observations, the pendulum is gently lowered to the knife-edge, and set swinging with an arc of about 5 millimetres amplitude. The pendulum must always be placed in the same position on the knife-edge. Of the two knife-edges Nos. I and II, only No. I was used.

The pendulum having been set swinging, the observer by means of a switch turns either of the chronometers on the flash apparatus and notes the coincidences. In timing coincidences a hack chronometer, placed on the table near the observer, is used. A complete set of coincidences consists of three, two up and one down, or two down and one up. Readings are taken with both chronometers on the flash apparatus. The hack chronometer is always compared with the observing chronometers at each set of coincidences. Readings of arc, thermometer, and manometer are made and recorded. After approximately eight hours the readings are again repeated. This constitutes a swing of the pendulum which is then stopped, and restarted, and the readings again repeated. This is done a third time, and at the end of twenty-four hours a second pendulum is installed, and three sets of readings are similarly taken on it. At the end of the first twenty-four hours a second comparison between the chronometers and the standard clock is made, or a second set of time observations (if possible) is taken. When a standard clock is available for comparison, such a comparison may be made once, twice, or three times a day. When the rates of the two chronometers are determined from star observations, such observations are generally taken at the beginning of the first swing of the first pendulum, and at the end of the third swing of the third pendulum. When on account of cloudy weather, it is impossible to get star observations at the end of complete sets of the three pendulums, then the pendulum observation must be continued until such time as the sky clears. It is believed that by swinging the pendulums continuously between time determinations, the effect of diurnal irregularities of rate are entirely eliminated, as it will not be by any other method, and this is strikingly shown by computing the mean periods of the three pendulums as determined from the two chronometers. The average difference at the different stations is less than $0^s.0000001$, and the maximum difference is $0^s.0000004$.

Below follows a set of observations:

Station: Cochrane. *Date*: 31st July, 1914.

Pendulum 1. Swing 1.

Bond No. 519.

			"19"	
D	13h	48m	13s	
			3m	17s
U	13	51	30	
			3	13
D	13	54	43	
		Mean	3	15

Dent No. 52866.

			"26"	
D	13h	50m	07s	
			3m	17s
U	13	53	24	
			3	16
D	13	56	40	
		Mean	3	16·5

Arc	Pressure	Temperature
mm.	mm.	°
2·6	23·0	17·15
3·0	25·0	
5·6	48·0	

			"38"	
D	21h	11m	06s	
			3m	14s
U	21	14	20	
			3	15
D	21	17	35	
		Mean	3	14·5

			"45"	
D	21h	11m	55s	
			3m	16s
U	21	15	11	
			3	12
D	21	18	23	
		Mean	3	14

Arc	Pressure	Temperature
mm.	mm.	°
1·2	29·0	17·25
0·7	27·0	
1·9	56·0	

NOTE.- The figures in quotation marks, as "19" above, are the seconds of the back chronometer at the even minutes of the observing chronometers.

DETERMINATION OF COEFFICIENTS.

As the Canadian pendulums were made at Washington under the supervisio
of the Coast and Geodetic Survey, and as a replica of the Washington apparatu
the results of the experiments with the latter for the determination of th
coefficients relating to temperature, atmospheric density and flexibility of suppo
were utilized for the Canadian pendulums. The results of the Washingto
observations will be given. For the purpose, pendulum B4 was used as a standar
to eliminate the rate of the chronometer, being swung in an adjoining room unde
uniform conditions, while A4, A5, A6 were successively swung under the variou
conditions desired to be investigated. Simultaneous swings were made with th
pendulums, using the same chronometer to operate both flash apparatuses b
means of suitable electrical connections. The true period of B4 being known, th
difference between this and the observed period must be due to rate of chronomete
which may therefore be computed for each swing, and the resulting rate correctio
applied to the observations with A. This splendid method of determinin
pendulum coefficients was first used by Airy, and has more recently been employe
by Von Sterneck.

TEMPERATURE COEFFICIENT.*

Pendulum.	At Low Temperature.		At High Temperature.		Differences		
	Temp. C.	Period (corrected except for temperature)	Temp. C.	Period (corrected except for temperature)	Temp. C.	Period.	Increase of period for 1° increase of temperature
		s		s		s	s
A4D	7·58	·5008466	29·41	·5009366	21·83	·0000900	·00000412
A4R	7·93	·5008474	29·41	·5009377	21·48	·0000903	·00000420
A5D	8·27	·5006758	29·33	·5007644	21·06	·0000886	·00000421
A5R	8·57	·5006768	29·19	·5007630	20·62	·0000862	·00000418
A6D	8·92	·5006425	27·27	·5007192	18·35	·0000767	·00000418
A6R	9·17	·5006428	26·94	·5007187	17·77	·0000759	·00000427
						Mean	·00000419

The mean of the values, 0ˢ.00000419, is adopted as the temperature coefficien
for the three pendulums.

* United States Coast and Geodetic Survey report, 1893, Appendix 1

PRESSURE COEFFICIENT.*

Pendulum	At Low Pressure		At High Pressure		Differences		Increase of period for 1 mm. increase of pressure at 0° C.
	Pressure reduced to 0° C.	Period corrected except for pressure.	Pressure reduced to 0° C.	Period corrected except for pressure.	Pressure.	Period.	
	mm.	s	mm.	s	mm.	s	s
VI	6·0	·5008450	94·5	·5008411	88·5	·0000041	·0000001(3
V	6·1	·5008429	96·1	·5008508	90·0	·0000080	·0000000(9
						Mean ...	·0000001(0

The pressure correction in the neighbourhood of 60 millimetres pressure, the adopted standard, is therefore $+.000000101\ (60-\frac{Pr}{1+.00367\ T})$, where Pr is the pressure reading and T is the temperature.

Flexure coefficient.—The horizontal component of the force acting on the knife-edge through the swinging pendulum causes the support to move in unison with the pendulum, and therefore affects the period of the oscillation. This movement is called the flexure of the pendulum support.

The movement or displacement is an exceedingly minute quantity. Several methods have been devised to measure it, such as using an auxiliary pendulum which is set in motion by the oscillation of the support under the influence of the standard pendulum; and by the static method which has been used until recently. In the static method a horizontal pull of 15 kilogrammes was applied at the height of the knife-edge, and the resulting displacement measured by means of a scale and microscope. But in none of these methods was the actual displacement of the support due to the swinging pendulum measured. There were certain very doubtful assumptions made in the static method, and to avoid these Mr. John F. Hayford, formerly of the United States Coast and Geodetic Survey, proposed the plan of using the interferometer to measure the absolute displacement of the support due to the oscillating pendulum, and to determine the effect of the

*United States Coast and Geodetic Survey report, 1894, Appendix 1

displacement upon the period of the pendulum. Mr. W. H. Burger of the Coa and Geodetic Survey staff made the observations for flexure with the interfero meter, and the method he employed will be given, as described by Mr. Burger i his report.*

"In determining the coefficient of flexure of the support in terms of the perio of the pendulum, simultaneous swings of two different pendulums were observe the period of each being determined by using the same two chronometers to opera both flash apparatuses. The pendulums were swung on separate piers, ar under nearly identical conditions except for flexure. One pendulum was ke swinging as a standard with no change of condition, while the other was swu under constant conditions except for the varying flexibility of the support. Th work was divided into "runs", each run being independent as far as observatio were concerned. The pendulums were swung in nominally eight-hour period with no renewal of pendulums, each run beginning and ending with a time s When all corrections had been applied to the period of the standard pendulu the flexure being constant throughout the run, the variation from the mean perio of the run shown by the individual swings was assumed to be due to the variati of the chronometer for the periods covered by the individual swings and whatever small observational errors might be present. As the period of the oth pendulum was approximately the period of the standard pendulum, it w assumed that its individual periods had the same corrections due to rate as t corresponding periods of the standard pendulum.

"When these corrections had been applied to the swings of the pendulu having varying flexure, it was found that the periods obtained for the vario swings differed. It was assumed that this variation was caused by the variati in flexure conditions, and that the change in period was proportional to t displacement of the support, and therefore proportional to the flexure as express in terms of fringe width.

"The following programme was u 1:

"Run A: Pendulum A4 under standard conditions, and B4 under standa conditions except for changes of flexure conditions, as follows:—swings 1 and small flexure; 3 and 4 large flexure; 5 and 6 medium flexure.

*United States Coast and Geodetic Survey report, 1910, Appendix 6

"Run B: Same as run A, except B4 under standard conditions and A4 under varying conditions of flexure.

"Run C: Like run A, with A5 in place of A4 and B5 in place of B4.

"The following are the results obtained: —

Pendulum.	Small Flexure.		Large Flexure.		Difference		Results
	Flexure.	Period corrected except for flexure.	Flexure.	Period corrected except for flexure.	Flexure.	Period.	
	Fringe.	s.	Fringe.	s.	Fringe.	s.	
B4	0·10	·5008099	0·370	·5008166			0·01 F = 2·43 in
	0·08	·5008177					7th place of
	0·07	·5008099					period
	0·083	·5008105	0·370	·5008166	0·287	·0000061	
A4	0·06	·5008409	0·322	·5008438			0·01 F = 1·32 in
	0·12	·5008400					7th place of
	0·06	·5008411					period
	0·080	·5008406	0·322	·5008438	0·242	·0000032	
A5	0·09	·5006635	0·26	·5006649			0·01 F = 1·50 in
			0·28	·5006674			7th place of
	0·090	·5006635	0·27	·5006662	0·180	·0000027	period

"Results weighted according to the difference in flexure give for a final mean 0.01 F = 1.70 in the seventh place of the period."

This was adopted as the flexure coefficient for the two sets of pendulums, and as the Canadian pendulums are nearly identical in construction and mounting, it is assumed 1.70 in seventh place of the period is the flexure coefficient.

RATING OF CHRONOMETERS.

To all the stations except Washington, clock signals were sent from the standar clock at the Dominion Observatory, and recorded on a chronograph sheet fo comparison with the chronometers used in the pendulum observations. Signa were sent once a day to Maniwaki, Kingston and Rooerval, and twice a da to all the other stations. When observing in Ottawa the Riefler sidereal cloc was used in all the observations; and in Washington, in March, time observation were made to determine the rates of the chronometers. In Washington, eac pendulum was swung between time sets, hence the values of the periods of th different pendulums are entirely independent of one another. The noon signa from the United States Naval Observatory were also used to rate the chronometer For the May observations in Washington, the noon signals alone were usec The Naval Observatory issues at the end of each month a table of correctio to the time of the noon signals for each day.

Below follow tables of chronometer comparisons, the deduced daily rate and the corrections to the periods of the pendulums due to clock rates. Whe a standard sidereal clock (such as the Riefler or the Howard of the Dominio Observatory), whose rate is accurately known from observation, is used for com parison or for sending time signals, the accuracy of pendulum determinations greater than when star observations are taken. Any errors in the observatio for rate of the standard clock largely disappear when the rate for a period time is deduced, whereas in field observations any error in the time observatio must enter directly into the pendulum period. An error of $\pm 0^s.05$ in a tim determination is not uncommon, and that gives an error of $\pm 0^s.0000003$ in th pendulum period.

CHRONOMETER RATES FROM OBSERVATIONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD

Station.	Date.	Chronometer 1823.			Chronometer Comparison.		Rel. rate per day	Daily rate 1841	Corrections to 7th Place of Period	
		T	ΔT	Daily rate	1823.	1841.			1823.	1841
	1914.	h. m.	s.	s.	h. m. s.	h. m. s.	s.	s		
Washington....	Mar. 26	7 59	51·991		8 43 49·77	8 44 00 00				
				3·775			0·751	4·526	219	263
	" 30	12 12	57·756		12 47 52·90	12 48 00 00				
				1·110			0·623	4·733	238	274
	Apr. 1	15 04	66·466		15 36 54·22	15 37 00 00				
				4·046			0·407	4·453	235	258
	" 3	8 00	73·367		8 43 54·92	8 44 00 00				

CHRONOMETER RATES FROM NOON SIGNALS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD

Station.	Date.	Noon signals on chronometer 1823.	Difference for one standard day.	Diff. of sidereal time between noons.	Daily rate 1823.	Chronometer Comparison.		Rel. daily rate.	Daily rate 1841	Corrections to 7th place of period	
						1823.	1841.			1823.	1841
	1914.	h. m. s.	m. s.	m. s.	s.	h. m. s.	h. m. s.	s.	s		
Washington	Mar. 27	12 07 20·41				12 09 50·39	12 10 00				
			3 52·95	3 56·56	3·600			0·808	4·408	209	256
	" 28	12 11 13·36				12 12 51·20	12 13 00				
			3 52·78	3 56·56	3·770			0·671	4·441	219	258
	" 30	12 18 58·92				12 09 52·54	12 10 00				
			3 52·39	3 56·55	4·149			0·584	4·733	241	275
	" 31	12 22 51·31				12 24 53·13	12 25 00				
			3 52·45	3 56·55	4·089			0·748	4·837	238	281
	Apr. 1	12 26 43·76				12 28 53·88	12 29 00				
			3 52·55	3 56·56	4·000			0·389	4·389	232	255
	" 2	12 30 36·31				12 31 54·27	12 32 00				
			3 52·40	3 56·55	4·139			0·289	4·428	240	257
	" 3	12 34 28·71				12 34 54·56	12 35 00				

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD

Station	Date.	Chronometer Comparisons			Relative rates		Daily rates			Corrections to 7th place of period	
		Bond	Negus	Riefler	B to R	N to R	Riefler	Bond	Negus	Bond	Negus
	1914	h. m. s.	h. m. s.	h. m. s.	s.	s.	s.	s.	s.		
Ottawa	Apr. 15	.....	23 44 00	23 43 29·66							
	" 15	23 47 00		23 46 52·96							
					−2·093	−0·949	−0·218	−2·311	−1·167	−134	−6
	" 15	.....	7 19 00	7 19 29·36							
	" 15	7 21 00		7 21 52·30							
					−3·289	2·072	−0·218	−3·507	2·290	−203	−13
	" 16	.....	14 16 00	14 15 28·41							
	" 16	14 18 00		14 17 51·70							
					2·983	−2·649	−0·218	3·201	−2·867	−186	−16
	" 16	.....	23 04 00	23 03 27·33							
	" 16	23 05 00		23 04 50·73							
					−2·862	−2·715	−0·218	−3·080	−2·933	−179	−17
	" 16	.....	6 57 00	6 56 26·39							
	" 16	6 57 00		6 56 49·84							
					−2·465	−2·281	−0·218	−2·683	−2·499	−156	−14
	" 17	.....	13 40 00	13 39 25·70							
	" 17	13 41 00		13 40 19·20							
					−2·712	−2·239	−0·218	−2·930	−2·457	−170	−14
	" 17	.....	22 59 00	22 58 24·68							
	" 17	22 59 00		22 58 48·32							
					−2·364	−1·934	0·218	−2·582	−2·152	−150	−12
	" 17	.....	6 48 00	6 47 24·05							
	" 17	6 48 00		6 47 47·55							
					−2·324	−1·966	−0·218	−2·542	−2·184	−147	−12
	" 18	.....	14 44 00	14 43 23·40							
	" 18	14 45 00		14 44 46·78							
					−1·735	−2·061	0·218	−1·953	−2·279	−113	−13
	" 18	.....	23 28 00	23 27 22·65							
	" 18	23 28 00		23 27 46·15							
					−2·394	−1·382	0·218	−2·612	−1·600	−151	−9
	" 18	.....	7 17 00	7 16 22·30							
	" 18	7 17 00	..	7 16 45·39							
					−2·411	−1·312	0·218	−2·629	−1·530	−152	−8
	" 19	.....	14 14 00	14 13 21·82							
	" 19	14 15 00		14 14 44·69							
					−1·735	−2·776	0·218	−1·953	−2·994	−113	−17
	" 19	.....	22 06 00	22 05 20·91							
	" 19	22 08 00		22 07 44·42							
					−2·045	−2·477	0·218	−2·263	−2·695	−131	−15
	" 19	.....	6 55 00	6 54 20·00							
	" 19	6 56 00		6 55 45·37							
					−2·142	−2·127	0·218	−2·360	−2·345	−137	−13
	" 19	.....	14 20 00	14 19 19·25							
	" 19	14 20 00		14 19 42·75							
					−1·968	−3·428	−0·218	−2·186	−3·646	−127	−21

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD *Continued.*

Station	Date	Chronometer Comparisons			Relative rates		Daily rates			Corrections to 7th place of period	
		Bond	Negus	Riefler	B to R	N to R	Riefler	Bond	Negus	Bond	Negus
	1914	h. m. s.	h. m. s.	h. m. s.	s.	s.	s.	s.	s.		
Ottawa	Apr. 20		23 43 00	23 42 17·91							
	" 20	23 44 00		23 43 41·94							
					−2·957	−2·510	−0·218	−3·175	−2·728	−184	−158
	" 20	. . . .	6 36 00	6 35 17·19							
	" 20	6 38 00		6 37 41·09							
					−2·395	−1·936	−0·218	−2·613	−2·154	−152	−125
	" 20	. .	14 39 00	14 38 16·56							
	" 20	14 39 00		14 38 40·29							
					−1·628	−3·455	−0·218	−1·846	−3·673	−107	−213
	" 21	.	23 20 00	23 19 15·31							
	" 21	23 21 00		23 20 39·70							
	" 24		6 28 00	6 27 15·23							
	" 24	6 30 00	.	6 29 12·62							
					−1·640	−1·488	−0·218	−1·858	−1·706	−108	−90
	" 24		14 32 00	14 31 44·73							
	" 24	14 33 00		14 32 12·07							
					−1·786	−0·948	−0·218	−2·004	−1·166	−116	−68
	" 25	.	23 24 00	23 23 44·38							
	" 25	23 25 00		23 24 11·41							
					−1·397	−0·570	−0·218	−1·615	−0·788	−94	−46
	" 25	. .	7 49 00	7 48 44·18							
	" 25	7 50 00		7 49 10·92							
	" 27	. .	1 21 00	1 20 41·80							
	" 27	1 22 00	. .	1 21 09·72							
					−1·957	−2·110	−0·218	−2·175	−2·328	−126	−135
	" 27	. .	7 50 00	7 49 41·23							
	" 27	7 52 00		7 51 09·19							
					−2·638	−1·608	−0·218	−2·856	−1·826	−166	−106
	" 27	. .	14 24 00	14 23 40·79							
	" 27	14 25 00	.	14 24 08·47							
					−2·790	−1·501	−0·218	−3·008	−1·719	−174	−100
	" 28	. . .	23 31 00	23 30 40·22							
	" 28	23 32 00	. . .	23 31 07·41							
	" 28	.	2 22 00	2 21 40·04							
	" 28	2 21 00		2 20 07·12							
					−2·424	−1·100	−0·218	−2·642	−1·318	−153	−76
	" 28	.	7 23 00	7 22 39·81							
	" 28	7 24 00		7 23 06·61							
					−2·635	−1·078	−0·218	−2·853	−1·296	−165	−75
	" 28	.	15 24 00	15 23 39·45							
	" 28	15 25 00		15 24 05·73							
					−2·571	−0·948	−0·218	−2·789	−1·166	−162	−68

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD—*Concluded*

Station	Date	Chronometer Comparisons			Relative rates		Daily rates			Corrections to 7th place of period	
		Bond	Negus	Riefler	B to R	N to R	Riefler	Bond	Negus	Bond	Negus
	1914	h. m. s.	h. m. s.	h. m. s.	s.	s.	s.	s.	s.		
Ottawa..	Apr. 29	.....	24 16 00	24 15 39·10							
	" 29	24 17 00	.....	24 16 04·78							
	" 29	.....	1 06 00	1 05 39·08							
	" 29	1 07 00	.....	1 06 04·79	1·400	−4·704	−0·218	−1·618	−4·922	− 94	−286
	" 29		6 47 00	6 46 37·77							
	" 29	6 48 00	.....	6 47 04·40	1·941	−4·493	−0·218	−2·159	−4·711	−125	−274
	" 29	.....	13 34 00	13 33 36·50							
	" 29	13 36 00	.....	13 35 03·85	1·979	−4·594	−0·218	−2·197	−4·812	−127	−279
	" 30	.....	23 39 00	23 38 34·57							
	" 30	23 40 00	.....	23 39 03·02							
	" 30	.....	0 20 00	0 19 34·50							
	" 30	0 21 00	.....	0 20 03·00	−2·235	−1·498	−0·218	−2·453	−1·716	−142	−100
	" 30	.....	6 54 00	6 53 34·09							
	" 30	6 54 00	.....	6 53 02·39							
	" 30	.....	7 48 00	7 47 34·06							
	" 30	7 46 00	.....	7 45 02·29	−2·489	−1·174	−0·218	−2·707	−1·392	−157	− 81
	" 30	.....	15 22 00	15 21 33·69							
	" 30	15 23 00	.....	15 22 01·50	−2·446	−1·058	−0·218	−2·664	−1·276	−155	− 74
	May 1	.....	23 59 00	23 58 33·31							
	" 1	24 01 00	.....	24 00 00·62							

DEDUCED RATE OF CHRONOMETER 1823 FROM NOON SIGNALS.

Station.	Noon Signals on Chronometer 1823.							Difference for one standard day.	Difference sidereal time between noons	Rate (daily) 1823
	May 6.	May 7.	May 8.	May 9.	May 10.	May 11.	May 12.			
	s.	s.	s.	s.	s.	s.	s.	m. s.	m. s.	s
Washington.....	25·34	18·62	.....	.....	.....	.....	.....	3 53·28		
	14·30	07·57	.....	.....	.....	.....	.....	·27		
	13·28	06·56	.....	.....	.....	.....	.....	·28		
	12·29	05·57	.....	.....	.....	.....	.....	·28		
	11·27	04·55	.....	.....	.....	.....	.....	·28		
								3 53·28	3 56·56	3·271
		18·62	11·91	.....	.....	.....	.....	3 53·29		
		18·41	11·72	.....	.....	.....	.....	·31		
		12·41	05·72	.....	.....	.....	.....	·31		
		11·43	04·74	.....	.....	.....	.....	·31		
		10·40	03·72	.....	.....	.....	.....	·32		
		09·42	02·74	.....	.....	.....	.....	·32		
								3 53·31	3 56·56	3·241
			11·91	05·23	.....	.....	.....	3 53·32		
			41·23	34·54	.....	.....	.....	·31		
			11·34	04·64	.....	.....	.....	·30		
			09·33	02·62	.....	.....	.....	·29		
								3 53·305	3 56·55	3·237
				05·23	58·26	.....	.....	3 53·03		
				54·19	47·22	.....	.....	·03		
				53·16	46·20	.....	.....	·04		
				52·19	45·21	.....	.....	·02		
				51·16	44·18	.....	.....	·02		
								3 53·028	3 56·56	3·522
					58·26	51·04		3 52·78		
					57·42	50·19		·77		
					27·51	20·29		·78		
					57·56	50·36		·80		
					27·67	20·46		·79		
								3 52·784	3 56·56	3·766
						23·23	16·38	3 53·15		
						22·22	15·37	·15		
						21·22	14·37	·15		
						20·19	13·34	·15		
						50·29	43·43	·14		
								3 53·148	3 56·56	3·402

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD

Station	Date	Chronometer Comparisons		Relative daily rate	Daily rates		Corrections to 7th place of period	
		1841	1823		1823	1841	1823	1841
	1914	h m s	h m s.	s.	s.	s.		
Washington	May 6	2 43 00·00	2 43 17·713					
	" 7	2 47 00·00	2 47 18·303	0·588	3·271	3·859	190	224
	" 8	2 51 00·00	2 51 19·403	1·097	3·241	4·338	188	252
	" 9	2 55 00·00	2 55 19·720	0·316	3·237	3·553	188	206
	" 10	2 59 00·00	2 59 20·020	0·299	3·522	3·821	204	222
	" 11	3 03 00·00	3 03 20·070	0·050	3·766	3·816	218	221
	" 12	3 07 00·00	3 07 21·090	1·017	3·402	4·419	197	256

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD
—*Continued*

Station.	Date	Chronometer Comparisons		Relative daily rate B to R	Daily Rates		Corrections to 7th place of period	
		Riefler	Bond		Riefler	Bond	Riefler	Bond
	1914	h. m. s.	h. m. s	s.	s	s.		
Ottawa, Ont	May 18	6 47 13·58	6 47 00 00					
	" 18	13 51 13·03	13 51 00 00	−1·868	−0·285	−2·153	17	−125
	" 19	22 48 12·29	22 48 00·00	−1·984	−0 285	−2 269	17	−132
	" 19	6 25 11·69	6 25 00·00	−1 891	−0 285	−2·176	17	126
	" 19	7 10 15·63	7 10 00·00					
	" 19	14 32 15·03	14 32 00·00	−1·955	0 285	−2 240	17	−130
	" 20	22 25 14·24	22 25 00·00	−2 405	−0 285	−2·690	17	−156
	" 20	23 06 14·20	23 06 00·00					
	" 20	6 35 15·51	6 35 00·00	−2·213	−0·285	−2 498	17	−145
	" 20	7 46 15·41	7 46 00·00					
	" 20	14 20 14·87	14 20 00·00	−1·974	−0 285	−2·259	17	−131
	" 21	23 40 14·05	23 40 00·00	−2·109	−0·285	−2 394	17	−139
	" 21	6 49 13·41	6 49 00·00	−2·148	−0·285	−2·433	−17	−141
	" 21	7 30 13·33	7 30 00·00					
	" 21	14 51 12·59	14 51 00·00	−2·416	−0 285	−2·701	−17	−157
	" 22	23 42 11·48	23 42 00·00	−3·010	−0·285	−3·295	−17	−191
	" 22	6 37 10·62	6 37 00·00	−2·984	−0·285	−3·269	−17	−190
	" 22	8 00 16·49	8 00 00·00					
	" 22	14 34 15·82	14 34 00·00	−2·449	−0·285	−2·734	−17	−159
	" 23	23 44 14·79	23 44 00·00	−2·697	−0·285	−2·982	−17	−173
	" 23	3 08 14·35	3 08 00·00					
	" 23	9 19 13·78	9 19 00·00	−2·212	−0·285	−2·497	−17	−145
	" 23	15 08 13·31	15 08 00·00	−1·939	−0·285	−2·224	−17	−130
	" 24	0 20 12·50	0 20 00·00	−2·113	−0·285	−2·398	−17	−139
	" 24	1 16 12 40	1 16 00·00					
	" 24	9 06 11·71	9 06 00·00	−2·114	−0·285	−2·399	−17	−139
				−2·156	−0·285	−2·441	−17	−142

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD
Continued

Station	Date	Chronometer Comparisons		Relative daily rate B to R	Daily Rates		Corrections to 7th place of period	
		Riefler	Bond		Riefler	Bond	Riefler	Bond
	1914	h. m. s.	h. m. s.	s	s	s		
Ottawa, Ont.	May 24	15 00 11 18	15 00 00 00					
				−1·453	−0·285	−1·738	17	−101
	" 25	0 15 10 62	0 15 00 00					
	" 25	1 18 10 56	1 18 00 00					
				2·521	−0·285	−2·806	17	−162
	" 25	10 32 09 59	10 32 00 00					
				2·900	−0·285	−3·185	17	−185
	" 25	17 44 08 72	17 44 00 00					
				−2·596	−0·285	−2·881	17	−168
	" 26	1 41 07 86	1 41 00 00					
				−2·148	−0·285	−2·433	17	−141
	" 26	7 43 07 32	7 43 00 00					
				2·933	−0·285	−3·218	17	−187
	" 26	14 55 06 41	14 55 00 00					
				−3·154	−0·285	−3·439	17	−199
	" 27	23 52 05 25	23 52 00 00					
				−2·978	−0·285	−3·263	17	−189
	" 27	6 43 04 40	6 43 00 00					
	" 27	7 56 16 29	6 56 00 00					
				−2·652	−0·285	−2·937	17	−170
	" 27	14 54 15 52	14 54 00 00					
				−2·112	−0·285	−2·397	17	−139
	" 28	0 20 14 69	0 20 00 00					
				−2·101	−0·285	−2·386	17	−138
	" 28	8 13 14 00	8 13 00 00					
	" 28	8 58 13 95	8 58 00 00					
				−2·677	−0·285	−2·962	17	−172
	" 28	16 03 13 16	16 03 00 00					
				−2·443	−0·285	−2·728	17	−158
	" 29	0 30 12 30	0 30 00 00					
				−1·989	−0·285	−2·274	17	−132
	29	3 31 12 05	3 31 00 00					
	" 29	7 40 11 72	7 40 00 00					
				−2·575	−0·285	−2·860	17	−166
	" 29	15 13 10 91	15 13 00 00					
				−2·716	−0·285	−3·001	17	−174
	" 30	0 35 09 85	0 35 00 00					

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD—*Continued*

Station	Date	Comparison of Chronometers			Relative Daily Rates		Daily Rates			Corrections to 7th place of period	
		Bond	Dent	Roelker	B to R	D to R	Roelker	Bond	Dent	Bond	Dent
	1914	h. m. s.	h. m. s.	h. m. s.	s.	s.	s.	s.	s.		
Manawaka, Que.	June 1	5 45 02·62	5 15 00								
	" 1	5 33 28 12		5 33 00							
	" 2	5 08 02 58	5 08 00		−1·571	0·040	−0·334	−1·908	−1·948	−11	··
	" 2	5 29 29·69		5 29 00							
	" 3	23 55 02 16	23 55 00								
	" 3	23 52 24 81		23 52 00							
	" 4	0 05 00·04	0 05 00		−1·484	2·105	0·334	−1·818	−3·923	−105	−228
	" 4	0 08 26 31	0 08 00	0 08 00							
Kingston, Ont.	June 9	4 46 02 12	4 46 00								
	" 9	5 13 45·20		5 13 00							
	" 10	4 41 00·28	4 41 00		−2·858	−1·846	−0·334	−3·192	−5·038	−185	−292
	" 10	4 44 48·00		4 44 00							
	" 11	4 43 58·25	4 44 00		−2·536	−2·027	−0·334	−2·870	−4·897	−166	−284
	" 11	4 46 50 54		4 46 00							
Roberval, Que.	June 16	12 20 05·68	12 20 00								
	" 16	11 07 21·80		11 07 00							
	" 17	10 33 01 71	10 33 00		+1·084	−4·267	−0·334	+0·750	−3·517	+44	−204
	" 17	10 48 20 73		10 48 00							
	" 18	10 10 59·38	10 11 00		−0·805	−2·368	−0·334	−1·139	−3·507	−66	−203
	" 18	10 04 21·51		10 04 00							
Tadoussac, Que.	June 22	6 55 55 41	6 55 00								
	" 22	6 49 54·61		6 49 00							
	" 22	14 45 55·17	14 45 00		0·000	−0·735	−0·334	−0·334	−1·069	−19	−62
	" 22	14 42 54·61		14 42 00							
	" 23	3 47 54 73	3 47 00		0·000	−0·810	−0·334	−0·334	−1·144	−19	−66
	" 23	3 21 54·61		3 21 00							
	" 23	12 35 54·51	12 35 00		+0·237	−0·600	−0·334	0·097	0·697	−6	−40
	" 23	12 28 54·52		12 28 00							
	" 24	2 48 54·95	2 48 00		−1·212	+0·743	−0·334	−1·546	−0·803	−90	−47
	" 24	2 55 55 25		2 55 00							

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD.—*Continued*

Station	Date	Comparison of Chronometers			Relative Daily Rates		Daily Rates			Corrections to 7th place of Period	
		Bond	Dent	Riefler	B to R	D to B	Riefler	Bond	Dent	Bond	Dent
	1914	h. m. s.	h. m. s.	h. m. s.	s	s	s	s	s		
Portneuf Que.	June 25	8 55 15·90	8 55 00								
	" 25	8 47 59·80	.....	8 48 00	2·057	−2·281	−0·334	−2·391	4·672	−139	−271
	" 26	1 26 14·33	1 26 00								
	" 26	1 21 01·22	.....	1 21 00	−2·109	−1·700	−0·334	−2·443	−4·143	−142	−240
	" 26	7 56 13·87	7 56 00								
	" 26	7 57 01·80	.....	7 57 00	1·544	−0·728	−0·334	−1·878	−2·606	−109	−151
	" 26	14 12 13·68	14 12 00								
	" 26	14 10 02·20	.....	14 10 00	−2·092	−1·977	−0·334	−2·426	4·403	−141	−255
	" 27	3 04 12·62	3 04 00								
	" 27	3 01 03 32	.....	3 01 00							
Ste. Jérôme Que.	July 1	8 59 44 03	8 59 00								
	" 1	8 52 27·73	.....	8 52 00	2·509	+0·331	−0·334	−2·843	2·512	−165	−146
	" 2	22 03 44·21	22 03 00								
	" 2	21 58 29·10	.....	21 58 00	2·447	+0·513	−0·334	−2·781	−2·268	−161	−131
	" 2	4 36 44·35	4 36 00								
	" 2	4 50 29·80	.....	4 50 00	2·533	+2·183	−0·334	−2·867	−0·684	−168	− 40
	" 4	21 59 31·61	.....	21 59 00							
	" 4	21 45 45·91	21 45 00		2·618	+3·166	−0·334	−2·952	+0·208	−171	+ 13
	" 4	3 45 46·70	3 45 00								
	" 4	3 51 32·25	.....	3 51 00							
Ste. Anne de Bellevue Que.	July 8	3 08 09·88	3 08 00								
	" 8	3 01 15·09	.....	3 01 00	2·659	−1·228	−0·334	−2·993	4·221	−174	−245
	" 8	10 11 09·52	10 11 00								
	" 8	10 16 15·90	.....	10 16 00	2·614	−1·431	−0·334	−2·948	−4·279	−171	−248
	" 9	3 51 08·54	3 51 00								
	" 9	3 48 17·81	.....	3 48 00	−2·088	−2·202	−0·334	−2·422	−4·624	−140	−268
	" 9	10 43 07·91	10 43 00								
	" 9	10 40 18·42	.....	10 40 00	−0·738	−3·792	−0·334	−1·072	−4·864	− 62	−282
	" 10	2 02 05·49	2 02 00								
	" 10	2 00 18·89	.....	2 00 00							

CHRONOMETER COMPARISONS AT PLACE — REDUCED CORRECTIONS TO PENDULUM

Station	Date		Comparison of Chronometers			Relative Daily Rate			Daily Rate		Correction to 7th Place of Period	
			Bond	Dent	Pownall	Bond to H	Dent to B	Howard	Bond	Dent	Bond	Dent
	1914		h m s	h m s	h m s	s	s	s	s	s		
Marlowe Obs.	July	14	6 48 45·61	6 38 00								
"	"	14	6 26 28·92		6 40 00							
						1·945	−1·456	1·014	2·959	1·569	172	250
	"	15	23 10 14 08	23 10 00								
	"	15	28 47 25 30		23 57 00							
						1·948	−0·910	1·014	2·962	0·877	172	22
	"	15	6 33 11 10	6 33 00								
	"	15	6 31 25 86		6 31 00							
						1·392	2·161	1·014	2·408	1·567	140	250
	"	16	23 19 12 89	23 19 00								
	"	16	28 25 26 84		27 25 00							
						1·543	−0·763	1·014	2·557	1·320	148	196
	"	16	6 14 42 07	6 14 00								
	"	16	6 43 27 30		6 43 00							
Eastwood Obs.	July	17	11 21 52 18	11 21 00								
"	"	17	11 16 48 10		11 16 00							
						3·256	+0·136	1·014	4·270	1·154	248	240
	"	18	3 14 52 27	3 14 00								
	"	18	3 11 50 26		3 11 00							
						2·538	−0·573	1·014	3·552	0·925	206	228
	"	18	10 57 52 15	10 57 00								
	"	18	11 19 51 12		11 19 00							
						2·420	+1·239	1·014	3·434	2·195	199	127
	"	19	3 25 53 90	3 25 00								
	"	19	3 23 52 74		3 23 00							
						2·506	+1·800	1·014	3·520	1·720	204	100
	"	19	11 01 53 57	11 01 00								
	"	19	11 20 53 57		11 20 00							
Cochrane Obs.	July	20	11 29 06 88	11 29 00								
"	"	20	11 27 59 90		11 28 00							
						−1·607	+0·321	1·014	2·681	2·360	155	130
	"	21	5 25 07 08	5 25 00								
	"	21	6 10 00 95		6 10 00							
						1·576	+0·705	−1·014	−2·590	−1·885	−150	109
	"	21	13 15 07 31	13 15 00								
	"	21	13 37 01 44		13 37 00							
						−1·628	−0·148	−1·014	−2·642	−2·790	−155	−162
	"	22	5 30 07 21	5 30 00								
	"	22	5 41 02 53		5 41 00							
						2·035	−0·623	1·014	3·049	2·426	177	141
	"	22	13 12 07 41	13 12 00								
	"	22	13 35 03 20		13 35 00							

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD -[illegible]

Station	Date	Comparison of Chronometers			Relative Daily Rates		Daily Rates.			Corrections to 7th place of Period	
		Bond	Dent	Riefler	B to R	D to B	Riefler	Bond	Dent	Bond	Dent
	1914	h. m. s.	h. m. s.	h. m. s.	s.	s.	s.	s.	s.		
Sault Ste Marie, Ont	July 24	17 10 49·01	17 10 00								
	" 24	17 21 14·29	. . . .	17 21 00	−2·753	−0·090	−0·207	−2·960	−3·050	−172	−177
	" 25	9 11 18·95	9 11 00								
	" 25	9 20 16·12	. . . .	9 20 00	+3·147	+1·796	−0·207	−3·354	−1·558	−195	− 90
	" 25	16 56 49·53	16 56 00								
	" 25	17 25 17·18	. . . .	17 25 00	+2·625	+0·684	−0·207	−2·832	−2·148	−165	−125
	" 26	9 26 50·00	9 26 00								
	" 26	9 25 18·93	. . . .	9 25 00	+4·055	+1·898	−0·207	−3·262	−1·364	−189	− 79
	" 26	17 24 50·06	17 24 00								
	" 26	17 21 19·94		17 21 00							

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD—*Continued*

Station	Date	Comparison of Chronometers			Relative Daily Rates		Daily Rates			Corrections to 7th place of Period	
		Bond	Dent	Riefler	B to R	D to B	Riefler	Bond	Dent	Bond	Dent
	1914	h. m. s.	h. m. s.	h. m. s.	s.	s.	s.	s	s		
Chapleau, Ont.	July 28	20 48 16·34	20 48 00								
	" 28	20 36 10·62	.....	20 36 00							
					−3·854	+0·494	−0·207	−4·061	−3·567	−236	−207
	" 28	3 07 16·97	3 07 00								
	" 28	3 27 11·72	.....	3 27 00							
					−3·895	+2·233	−0·207	−4·102	−1·869	−238	−108
	" 29	18 16 18·38	18 16 00								
	" 29	18 29 14·16	.....	18 29 00							
	" 29	2 14 18·84	2 14 00								
	" 29	2 30 15·07	.....	2 30 00							
					−3·188	+1·738	−0·207	−3·395	−1·657	−197	− 96
	" 30	18 15 20·00	18 15 00								
	" 30	18 41 17·22	.....	18 41 00							
					−3·409	+2·284	−0·207	−3·616	−1·332	−210	− 77
	" 30	1 11 20·66	1 11 00								
	" 30	1 26 20·73	1 26 00								
	" 30	1 35 18·20	.....	1 35 00							
					−0·566	−1·021	−0·207	−0·773	−1·794	− 45	−104
	" 31	15 32 20·13	15 32 00								
	" 31	15 34 18·53	.....	15 34 00							
					−0·235	−1·230	−0·207	−0·442	−1·672	− 26	− 97
	" 31	22 32 19·77	22 32 00								
	" 31	22 43 18·60	.....	22 43 00							
Port Arthur, Ont.	Aug. 3	10 11 40·33	10 11 00								
	" 3	10 09 30·06	.....	10 09 00							
					−1·609	+2·204	−0·207	−1·816	+0·388	−105	+ 23
	" 4	1 56 11·78	1 56 00								
	" 4	1 49 31·11	.....	1 49 00							
					1·330	+2·956	−0·207	−1·537	+1·419	− 89	+ 82
	" 4	10 08 42·79	10 08 00								
	" 4	10 07 31·57	.....	10 07 00							
					1·310	+2·484	−0·207	−1·517	+0·967	− 90	+ 56
	" 5	[illegible]	31	1 47 00							
	" 5	[illegible]	3	.....	1 52 00						
					1·390	+2·365	−0·207	−1·597	+0·768	− 93	+ 45
	" 5	9 48 15·20	9 48 00								
	" 5	9 59 32·90	.....	9 59 00							

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD—*Continued*

Station	Date	Chronometer Comparisons		Relative Daily Rate	Daily Rates		Corrections to 7th Place of Period	
		Riefler	Bond	B to R	Riefler	Bond	Riefler	Bond
	1911	h. m. s.	h. m. s.	s.	s.	s.		
Ottawa—Con.	Aug. 11	11 12 42 14	11 13 00 00					
				+3·764	−0·207	+3·971	12	2
	12	16 41 41 27	16 41 00 00					
				+3·846	−0·207	+4·053	12	2
	13	1 14 39 00	1 14 00 00					
				+2·675	−0·207	+2·882	12	1
	13	9 40 58 90	9 40 00 00					
				+2·488	−0·207	+2·695	12	1
	14	17 00 58 20	17 00 00 00					
				+3·325	−0·207	+3·532	12	2
	14	1 14 36 99	1 14 00 00					
				+3·671	−0·207	+3·878	12	2
	14	9 24 35·82	9 25 00 00					
	14	10 25 35·71	10 25 00 00	+3·503	−0·207	+3·710	−12	−2
	14	16 35 34 81	16 35 00 00					
	Sept. 8	20 48 20·72	20 48 00 00					
				−1·875	−0·099	−1·974	−6	−1
	8	3 58 3 46	3 58 00 00					
				−2·019	−0·099	−2·118	−6	−1
	9	12 03 19 48	12 03 00 00					
				−1·517	−0·099	−1·616	−6	−1
	9	20 07 18 97	20 07 00 00					
	9	20 37 18 93	20 37 00 00					
				0·777	−0·099	0·876	−6	−1
	9	3 43 18 70	3 43 00 00					
				−0·972	−0·099	−1·071	−6	−1
	10	11 52 18 57	11 52 00 00					
				0·576	−0·099	−0·675	6	1
	10	19 47 18 48	19 47 00 00					

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD—*Continued*

Station	Date	Comparison of Chronometers			Relative Daily Rates		Daily Rate			Correction to 7th Place of Period	
		Bond	Dent	Riefler	B to R	D to B	Riefler	Bond	Dent	Bond	Dent
	1944	h m s	h m s	h m s	s	s	s	s	s		
Rose Point, Ont.	Aug 18	15 14 24·42	15 14 00								
	" 18	15 12 29·50		15 12 00							
					1·685	0·220	0·099	1·784	2·004	104	116
	" 19	4 20 24·30	4 20 00								
	" 19	4 18 30·42		4 18 00							
					−0·790	0·463	0·099	0·889	1·352	52	78
	" 19	10 33 24·18	10 33 00								
	" 19	10 41 30·63		10 41 00							
					0·812	0·668	−0·099	0·911	1·579	53	91
	" 19	15 10 24·05	15 10 00								
	" 19	15 07 30·78		15 07 00							
Whitby, Ont.	Aug 20	18 03 55·39	18 03 00								
	" 20	18 01 22·43		18 01 00							
					−2·198	+0·616	−0·099	−2·297	1·681	133	98
	" 21	6 54 55·72	6 54 00								
	" 21	7 07 23·63		7 07 00							
					−2·005	−0·513	0·099	2·104	1·791	122	104
	" 21	13 02 55·80	13 02 00								
	" 21	12 59 24·12		12 59 00							
					1·813	+0·692	0·099	1·912	1·220	111	71
	" 21	19 58 56·00	19 58 00								
	" 21	20 00 24·65		20 00 00							
					−2·514	+1·672	−0·099	2·610	0·938	−151	54
	" 22	8 53 56·90	8 53 00								
	" 22	9 00 26·01		9 00 00							
Woodstock, Ont.	Aug 21	17 28 04·35	17 28 00								
	" 24	17 30 26·58		17 30 00							
					−1·030	+0·211	0·099	1·159	0·948	67	55
	" 25	7 07 04·47	7 07 00								
	" 25	7 05 26·98		7 05 00							
					0·806	+0·242	0·099	0·905	0·663	52	38
	" 25	13 59 04·61	13 59 00								
	" 25	13 56 27·21		13 56 00							
					+0·717	+0·358	−0·099	0·816	0·458	47	27
	" 25	20 01 04·72	20 01 00								
	" 25	19 58 27·42		19 58 00							
					−1·684	+0·892	0·099	1·783	0·891	103	52
	" 26	10 17 05·23	10 17 00								
	" 26	10 25 28·42		10 25 00							

CHRONOMETER COMPARISONS AND DEDUCED CORRECTIONS TO PENDULUM PERIOD—*Concluded*

Station	Date	Comparison of Chronometers			Relative Daily Rates		Daily Rates			Correction to 7th Place of Period	
		Bond	Dent	Riefler	B to R	D to B	Riefler	Bond	Dent	Bond	Dent
	1914	h. m. s.	h. m. s.	h. m. s.	s.	s.	s.	s.	s.		
Windsor,	Aug. 27	12 41 44·60	12 41 00								
Ont.	" 27	12 48 29·12	......	12 48 00							
					[illegible]·160	+2·078	−0·099	−3·259	−1·181	−189	− 09
	" 27	20 46 45·30	20 46 00								
	" 27	20 42 30·16	......	20 42 00							
					[illegible]·041	+2·433	−0·099	−3·140	−0·707	−182	− 11
	" 28	12 39 46·91	12 39 00								
	" 28	12 45 32·18	......	12 45 00							
					2·862	+2·857	−0·099	−2·961	−0·104	−172	− 6
	" 28	20 58 47·90	20 58 00								
	" 28	20 53 33·15	....	20 53 00							
					3·434	+3·670	−0·099	−3·533	+0·137	−205	+ 8
	" 29	12 20 50·25	12 20 00								
	" 29	12 24 35·37	......	12 24 00							

REDUCTION OF OBSERVATIONS.

The periodic time as determined from the coincidence period must be corrected for arc, temperature, pressure, rate and flexure. The reduction must be made to infinitely small arc; the standard temperature is 15° Centigrade; the standard density of air in the chamber is 60 millimetres at 0° Centigrade, and this standard was closely realized in each experiment. The correction for flexure was determined experimentally at the different stations.

Arc correction.—The initial and final semi-arcs of oscillation for each swing are given on the scale near the point of the pendulum. The correction to reduce the time of oscillation to what it would be were the pendulum swinging in an infinitely small arc was computed by means of Borda's formula:

$$b = \frac{Mn \, . \sin\,(\varphi + \varphi^1) \, . \sin\,(\varphi - \varphi^1)}{32\,(\log \sin \varphi - \log \sin \varphi^1)},$$

where M is the modulus of the common logarithmic system, n the number of oscillations actually made, φ the initial semi-arc, φ^1 the final semi-arc,

and b the quantity to be added to n oscillations in order to obtain the number that would have been made in the same interval had the arc been infinitely small.

Transforming this expression into a correction to the period, it becomes with a sufficient degree of accuracy when the arc is small,

$$A = \frac{PM}{32} \cdot \frac{\sin(\varphi + \varphi^1) \cdot \sin(\varphi - \varphi^1)}{\log \sin \varphi - \log \sin \varphi^1},$$

where P is the period of the pendulum in seconds, and A is the amount to be subtracted from the period to reduce to infinitely small arc.

Temperature correction.—Each period is corrected for the difference between the mean temperature of the swing and 15° Centigrade, adopted as a standard. The temperature coefficient as determined above is $0^s{\cdot}00000419$ for each degree Centigrade. The correction to the period is, therefore, $(15° - T)\ (0^s{\cdot}00000419)$, where T is the observed temperature in degrees Centigrade.

Pressure correction.—An atmospheric density represented by air at a temperature of 0° Centigrade, and under a pressure of 60 millimetres of mercury, is taken as the standard, and periods are corrected for the difference between the conditions under which observations are made and this standard. The receiver is always exhausted to a point where the density therein nearly approaches the standard, so that this correction takes the form of

$$C = k\ (60 - \frac{Pr}{1 + {\cdot}00367\ T}),$$

where C is the correction in seconds (to be subtracted if observed density is above the standard and added if below the standard), k is the pressure coefficient, or variation in period for change of 1 millimetre in pressure (at 0° Centigrade), Pr is the observed pressure in millimetres of mercury, and T is the mean temperature of swing in degrees Centigrade. The determination of k was described under determination of pressure coefficient. Its value as determined is $0^s{\cdot}000000101$.

Rate correction.– The periods are reduced to sidereal time by correcting for the rate of the chronometer. This may be applied conveniently by the formula, $D = 0^s{\cdot}00001157\ R.P.$, where D is the correction to period (to be subtracted if chronometer is gaining, and added if losing), R is the rate of the chronometer, and P is the period of the pendulum in seconds.

Flexure correction. In observing flexure by means of the interferometer, there is presented the problem of finding the shift, or displacement of the fringe due to the oscillation of the pendulum, in terms of the width of one fringe.

The principle of the interferometer is shown in Fig. 2.

Fig. 2

The beam from the source of light (*) with its rays made parallel by a lens, L, strikes the rear or second surface of the plate, S, and separates, part of it being reflected to the plane mirror, P, returns exactly on its own path through S, and then through C to T where it is examined by a telescope, T. The other part goes through the plate, S, passes through the plate, C, and is reflected by the mirror, M, returns on its path through C to the plate, S, where it is reflected so as to unite with the first ray as to produce interference. The result is a series of bands in the form of a grating, as shown in Fig. 3, the dark band being produced when the two wave-trains differ by one-half a wave-length of light, and the light bands when they are in the same phase.

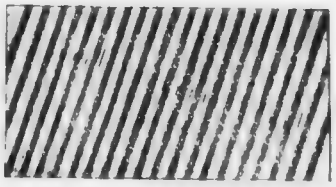


FIG. 3. FRINGES AND SCALE.

As one mirror is attached to the pendulum receiver and the remainder of the interferometer is mounted on a support entirely independent of the pendulum receiver, it is easily seen that any movement in the pendulum case will cause a shift or displacement of the fringes in the interferometer. Owing to the two parts of the interferometer being mounted on separate and independent supports, and the consequent instability in relative position of its parts, vibrations from sources other than the oscillating pendulum cause shifting of fringes, but they are erratic and are seldom mistaken for the shift due to the pendulum. Since the pendulum makes one complete swing in one-half a second, the shift of fringes will occur as a half-second shift across the field. It is the magnitude of this half-second movement which it is desired to measure. This movement is a measure of the amount of flexure in the pendulum case caused by the oscillation of the pendulum.

The method employed to determine the flexure at the pendulum stations was to observe the width of a fringe in terms of the divisions of the scale in the telescope, and then observe the amount of the shift or displacement of the fringe-band in terms of the scale divisions. The second quantity divided by the first will give the shift of the fringes in terms of their width.

In the use of the interferometer it is essential that a monochromatic light be used, as it is necessary to know the wave-length. In selecting a monochromatic light to use with the interferometer the sodium light was chosen, as it could very easily be obtained by the use of sodium chloride and an alcohol flame.

If the fringes shift, or are displaced one fringe-width due to the motion of the pendulum, it is easily seen that the pendulum case has moved

through a distance equal to one-half the wave-length of the light used, for a change of distance between the thinly silvered plate and the mirror on the pendulum case causes a change in the total path of the ray to and from that mirror by double that amount, so that if the length of the ray of light used is known we have a means of computing the movement of the case.

The wave-length of sodium light is practically 0·58 microns, and therefore a shift or displacement of the fringe by an amount equal to one fringe-width means a displacement of the pendulum case of 0·29 microns.

The following is a specimen of record and computation in the measurement of flexure in the field (Liskeard, Ont., 19th July, 1914).

Semi-Arcs		Total Arcs	Width of Fringe			Movement of Fringe			F = Displacement per 5 mm. of Arc
C	D		A	B	Diff.	A	A	Diff	
mm.	mm.	mm.							
6·8	7·6	14·4	4·0	7·0	3·0	4·0	4·5	0·5	
			3·0	5·6	2·6	3·0	3·5	0·5	
			5·0	8·0	3·0	5·0	5·4	0·4	
			1·0	6·4	2·4	4·0	4·3	0·3	$\frac{0·44 \times 5}{2·80 \times 13·9}$
6·3	7·1	13·4	3·0	6·0	3·0	3·0	3·5	0·5	$= 0·056$
				Mean...	2·80			0·44	
6·3	7·1	13·4	4·0	7·5	3·5	4·0	4·6	0·6	
			6·0	9·0	3·0	6·0	6·5	0·5	
			3·2	6·4	3·2	3·2	3·7	0·5	
			6·0	9·0	3·0	6·0	6·5	0·5	$0·54 \times 5$
6·1	6·9	13·0	4·0	7·0	3·0	4·0	4·6	0·6	$3·14 \times 13·20$
				Mean...	3·14			0·54	$= 0·064$
10·0	10·8	20·8	4·0	7·0	3·0	4·0	5·0	1·0	
			2·0	5·2	3·2	2·0	2·9	0·9	
			2·0	5·6	3·6	2·0	2·8	0·8	
			1·0	7·2	3·2	4·0	4·8	0·8	$\frac{0·86 \times 5}{3·20 \times 20·20}$
9·6	10·4	20·0	5·0	8·0	3·0	5·0	5·8	0·8	$= 0·066$
				Mean...	3·20			0·86	
9·6	10·4	20·0	2·5	6·0	3·5	2·5	3·5	1·0	
			5·0	8·0	3·0	5·0	5·9	0·9	
			5·0	9·0	4·0	5·0	6·0	1·0	$1·00 \times 5$
			5·0	9·0	4·0	5·0	6·1	1·1	$3·54 \times 19·30$
8·9	9·7	18·6	6·0	9·2	3·2	6·0	7·0	1·0	$= 0·074$
				Mean	3·54			1·00	

The correction for flexure is the mean of 0·056, 0·064, 0·066 and 0·074, or, 0·065 fringe per 5 millimetres of arc. Correction = 6·5 × 1·70, or 11 in seventh place of period of half-seconds pendulum.

VARIATION IN LENGTHS OF PENDULUMS.

Pendulums 1, 2 and 3 were swung twice, both at Washington and at Ottawa. It was found that the results from pendulums 1 and 3 agreed, while those from pendulum 2 seemed to be in error. Also, between the first and second observations at Ottawa, pendulum 2 changed its period from 0·5014643 second to 0·5014306 second. No apparent reason for this large change can be given, unless the pendulum had been injured in shipment. A careful examination of the pendulum and the support failed to show any traces of injury, and it was decided to commence the field work. At the first station, Maniwaki, pendulum 2 instead of swinging the full eight-hour period, only swung about three hours. Another careful examination of the pendulum and the agate edges was made, but nothing was found to account for the very peculiar and unsatisfactory behaviour of this pendulum. It was then decided to continue observing, but to use only the two pendulums 1 and 3.

During the season neither of these pendulums kept the same length. At all the stations from Ottawa to Ste. Anne-de-Bellevue there was agreement between the two pendulums, but on taking observations at Mattawa it was immediately noticed that the periods had changed relatively to one another. Observations were continued at all the stations in northern Ontario, and after finishing at Port Arthur the pendulums were brought to Ottawa and re-standardized. It was found that the period of pendulum 1 for Ottawa had changed from 0·5012993 to 0·5013267 second, and the period of pendulum 3 had changed from 0·5014157 to 0·5014101 second. The pendulums were then taken to Rose Point, where the periods agreed with the new values at Ottawa. However, on the journey from Rose Point to Whitby there was another change. The stations, Whitby, Woodstock and Windsor, were observed and the pendulums were returned to Ottawa and again standardized. Pendulum 3 was found still to have the period 0·5014101

second, while pendulum 1 had changed from 0·5013267 to 0·5013208 second. These changes in the lengths of pendulums are very disconcerting, and if it had not been possible to have returned to the base point and re-standardized them, the season's work would have been seriously impaired. However, all the stations have a tie to the base point at Ottawa.

What happened to the pendulums is, of course, a matter of which there is no certainty. The only thing that could change the period of a pendulum other than a blow, would be a looseness in some part of the system. For instance, there might be looseness in one of the following:

The bob on the stem.

The head on the stem.

The agate plane in the brass box.

Between the brass box holding the agate plane and the head of the pendulum.

Of either one of the two mirrors attached to the pendulum, or a tilting of the plane endwise so that the pendulum rests on one end of the knife-edge.

With regard to pendulum 2, there must have been a rubbing of the parts of the pendulum, on either the prongs of the lifting device, the scale for reading the arc, or some part of the apparatus that holds the knife-edge. A careful examination failed to discover any cause for the behaviour of this pendulum.

It may be of interest to state that one of the pendulums of the United States Coast and Geodetic Survey changed its length in 1909 by a very appreciable amount. During the past season it changed back to nearly its original length; a careful examination of all parts of this pendulum failed to show any defects, and the only remedy is to rebuild the pendulum in a most substantial manner. The whole value of pendulum observations depends on the invariability of the pendulum, therefore every care must be taken to insure that property. Only a change of very few microns in the length is necessary to affect the period materially.

Little difficulty was experienced in obtaining the right degree of pressure. The air pump worked satisfactorily and the receiver held well, except at two stations, Sault Ste. Marie and Chapleau. During the last swing at Sault Ste. Marie, the air started to leak into the case. It was thought that the leak was around the cap, but at Chapleau it still continued, and a careful examination revealed a wearing of one of the stop-cocks on the base of the receiver. The foreman in the C.P.R. shops at Chapleau was good enough to grind the defective part. The result was that the leak was very much reduced, and the observations were allowed to proceed.

PERIODS OF THE PENDULUMS, OBSERVATIONS AND REDUCTIONS.

In the following tables are the reductions of the periods of the three pendulums 1, 2 and 3, for Washington and Ottawa; and of the two pendulums 1 and 3 for all the field stations.

PENDULUM OBSERVATIONS AND REDUCTIONS

Station: Washington, D.C.

Date 1914	Swing number	Pendulum	Position	Knife-edge	Chronometer No. 1923	Chronometer No. 1940	Coincidences Estimated	Age Initial	Age Final	Temperature	Pressure	Correction for Pressure	Correction for Temperature	Correction for Rate	Correction for Error of Clock	Period corrected for Rate, Temperature, Pressure, Error of Clock
					s.	s.		days	days	° F.	ins.	s.	s.	s.	s.	s.
May 26	1	1	D	I	178·96	179·82	179·82	4·6	4·5	68·30	29·30					
27	2	1	D	I	179·16	179·74	179·74	5·2	5·1	67·15	29·38					
27	3	1	D	I	178·64	179·85	179·85	5·7	5·6	71·90	29·34					
27	4	1	D	I	178·64	179·17	179·17	5·6	5·5	73·70	29·34					
28	5	1	D	I	178·53	178·88	178·88	5·6	5·5	66·85	29·34					
28	6	1	D	I	177·90	178·86	178·86	6·3	6·2	70·05	29·34					
28	7	1	D	I	178·37	178·85	178·85	6·5	6·4	68·75	29·34					
29	8	1	D	I	178·69	178·96	178·96	7·5	7·4	72·65	29·34					
29	9	1	D	I	178·51	179·24	179·24	7·8	7·7	68·75	29·34					
29	10	1	D	I	179·14	179·35	179·35	8·0	7·9	67·80	29·34					
30	11	1	D	I	179·16	179·46	179·46	8·4	8·3	70·75	29·34					
30	12	1	D	I	179·26	179·91	179·91	8·7	8·6	72·85	29·34					
30	13	1	D	I	179·52	179·81	179·81	8·9	8·8	68·80	29·34					

Rate determined from star observations.

Mar. 27	3	1	D	I	178 64	179 55	5 7	2 1	13 86	51 20	5014354	5015992	−12	+48	11			11	5014279	5014254	
" 27	4	1	D	I	178 64	179 17	5 6	2 2	14 23	53 70	5014004	5015993	−13	+42	+09	+268	+256	11	5014290	5014290	
" 28	5	1	D	I	178 53	178 88	5 6	2 06	14 50	55 85	5014042	5014015	−12		+06	+270	+25	11	5014292	5014272	
																Mean			5014284	5014284	5014284
" 28	6	1	D	I	177 90	178 86	6 4	2 2	14 92	51 05	5014090	5014016	−14	+10	+04	+274	+258		5014259	5014259	
" 28	7	1	D	I	178 47	178 85	4 5	1 4	15 07	61 75	5014054	5014018	−07	−01	+01	+271	+258	11	5014255	5014256	
" 29	8	1	D	I	178 60	178 96	4 5	1 9	14 80	52 65	5014050	5014035		−08	+10	+274	+258	11	5014284	5014284	
" 29	9	1	D	I	178 51	179 24	4 8	1 7	14 38	54 75	5014044	5014038	−09	−25	+08	+269	+258	11	5014257	5014258	
" 29	10	1	D	I	179 14	179 45	4 9	1 4	14 04	57 80	5013965	5014078	08	+45	05	+274	+258	11	5014240	5014268	
" 30	11	1	D	I	179 16	179 46	5 4	2 0	13 65	60 75	5013991	5015969	1	5	+02	+274	+258	11	5014240	5014268	
																Mean			5014259	5014268	5014264
																				Mean	5014264

Rate determined from noon-signals

Mar. 31	1	2	D	I	160 14	160 40	6 3	2 0	13 31	53 20	5015660	5015685	−14	+57	+09	+268	+274	11	5015959	5015959	
" 31	2	2	D	I	159 91	160 50	5 0	1 6	13 28	60 00	5015677	5015626	08	+72	05	+268	+274	11	5015971	5015956	
" 31	3	2	D	I	160 05	160 47	5 2	1 3	13 31	66 30	5015666	5015625	−08	+71	03	+268	+274	11	5015951	5015944	
Apr. 1	4	2	D	I	160 10	160 42	5 5	2 1	13 18	57 15	5015654	5015633	−12	+76	+05	+268	+274	11	5015961	5015961	
" 1	5	2	D	I	159 88	160 35	5 2	1 9	13 11	64 35	5015686	5015640	11	+79	01	+268	+274	11	5015960	5015974	
" 1	6	2	D	I	160 09	160 [illegible]	5 5	1 9	13 19	55 70	5015665	5015644	12	+76	+07	+268	+274	11	5015976	5015976	
																Mean			5015961	5015965	[illegible]

Rate determined from star-observations

Mar. 31	2	2	D	I	159 91	160 50	5 0	1 6	13 28	60 00	5015677	5015626	−08	+72	05	+268	+281	11	5015971	5015956	
Apr. 1	3	2	D	I	160 05	160 47	5 2	1 3	13 31	66 30	5015666	5015625	−08	+71	[illegible]		+281	11	5015951	5015944	
" 1	4	2	D	I	160 10	160 42	5 5	2 1	13 18	57 15	5015654	5015633	−12	+76		[illegible]	+281	11	5015961	5015961	
																			5015966	5015965	5015965

Rate determined from noon-signals

PENDULUM OBSERVATIONS AND REDUCTION (continued).

Station: Washington, D.C. (continued) — Observer: E. A. Mc Donald

Date	Swing number	Pendulum	Position	Knife-edge	Coincident Intervals: Chronometer No. 1823	Coincident Intervals: Chronometer No. 1841	Arc: Initial	Arc: Final	Temperature	Pressure	Period Uncorrected: Chronometer No. 1823	Period Uncorrected: Chronometer No. 1891	Corrections for Diurnal Rate: Arc.	Corrections for Diurnal Rate: Temp.	Corrections for Diurnal Rate: Press.	Rate: 1823	Rate: 1841	Hour.	Clock Gain: Chronometer No. 1823	Clock Gain: Chronometer No. 1841	Mean
1904					s.	s.	mm	mm	°	mm	s.	s.							s.	s.	
Nov. 7	1	3	D	I	165·47	165·56	5·4	1·8	13·38	55·50	·5015152	·5015149	−·10	+·68	−·07	−·245	−·258	11	·5015441	·5015458	
	2	3	D	I	165·19	165·52	5·4	1·5	13·43	64·50	·5015180	·5015150	−·09	+·66	−·02	−·245	−·258	11	·5015479	·5015452	
	3	3	D	I	165·50	165·67	5·2	1·7	13·63	58·35	·5015151	·5015136	−·11	+·57	−·05	−·245	−·258	11	·5015426	·5015434	
	4	3	D	I	165·41	165·26	5·2	1·4	13·61	68·80	·5015169	·5015174	−·09	+·58	−·04	−·245	−·258	11	·5015438	·5015466	
	5	3	D	I	164·47	165·21	5·6	1·7	14·53	60·75	·5015247	·5015175	−·12	+·20	−·02	−·245	−·258	11	·5015482	·5015452	
																Means			·5015449	·5015448	·5015449

Rate determined from star observations.

Nov. 2	2	3	D	I	165·19	165·52	5·4	1·5	13·43	64·50	·5015180	·5015150	−·09	+·66	−·02	−·240	−·257	11	·5015464	·5015451	
	3	3	D	I	165·50	165·67	5·2	1·7	13·63	58·35	·5015151	·5015136	−·10	+·57	−·05	−·240	−·257	11	·5015432	·5015434	
	4	3	D	I	165·41	165·26	5·2	1·4	13·61	68·80	·5015169	·5015174	−·09	+·58	−·03	−·240	−·257	11	·5015444	·5015466	
																Means			·5015447	·5015450	·5015449

Rate determined from noon signals.

PENDULUM OBSERVATIONS AND REDUCTIONS—(Concluded)

Station: OTTAWA, ONT. Observers: L. A. M. DRUMMOND

Date	Set number	Pendulum	Face	Knife-edge	Coincidence Interval Chronometer: Local	Coincidence Interval Chronometer: Noon	Arc: Initial	Arc: Final	Temperature	Pressure	Period Uncorrected Chronometer: Local	Period Uncorrected Chronometer: Noon	Corrections for Decimal Place: Δ	Rate: Total	Rate: Pendulum	Rate: B	Rate: N	Flange	Period Corrected Chronometer: Local	Period Corrected Chronometer: Noon	Period Corrected Mean
1914.					s.	s.	mm.	mm.	°	mm.											
Apr. 15	1	1	D	I	189·54	190·46	5·0	1·9	17·91	43·50	·5013225	·5013161	−10	−122	+19	−134	− 68	−11	·5012967	·5012936	·5012
" 15	2	1	D	I	188·81	187·89	5·0	2·0	18·93	45·85	·5013276	·5013341	−10	−165	+17	−133	−203	−11	·5012974	·5012960	·5012
" 16	3	1	D	I	188·43	188·46	4·8	1·8	18·95	48·60	·5013303	·5013322	−09	−166	+14	−166	−186	−11	·5012965	·5012964	·5012965
" 16	4	1	D	I	188·58	18 46	5·4	1·9	18·51	50·00	·5013292	·5013301	−11	−147	+13	−170	−179	−11	·5012966	·5012966	·5012
" 16	5	1	D	I	189·05	188·90	5·6	2·0	18·11	51·50	·5013259	·5013270	−12	−130	+12	−145	−156	−11	·5012973	·5012973	·5012973
" 17	6	1	D	I	189·51	189·05	5·0	1·6	17·71	53·45	·5013227	·5013259	−08	−114	+10	−143	−170	−11	·5012961	·5012966	·5012964
																Means			·5012968	·5012968	·5012968
Apr. 17	1	1	D	I	190·16	190·03	4·7	2·0	16·96	46·60	·5013182	·5013191	−09	− 82	+16	−126	−135	−11	·5012970	·5012970	·5012970
" 20	2	1	D	I	188·04	189·12	5·4	1·6	19·75	52·20	·5013331	·5013254	−09	−199	+11	−157	− 81	−11	·5012966	·5012966	·5012966
" 20	3	1	D	I	187·87	189·06	5·3	1·5	19·83	55·00	·5013341	·5013258	−09	−202	+09	−155	− 74	−11	·5012973	·5012971	·5012
																Means			·5012970	·5012969	·5012
																		Means			·5012
Apr. 17	1	3	D	I	173·79	174·04	5·5	1·8	17·84	48·50	·5014427	·5014406	−10	−119	+15	−150	−125	−11	·5014152	·5014156	·5014154
" 17	2	3	D	I	173·42	173·73	6·1	1·9	18·28	50·70	·5014458	·5014432	−14	−137	+14	−147	−127	−11	·5014163	·5014157	·5014160
" 17	3	3	D	I	173·96	173·77	5·8	1·6	18·16	52·65	·5014413	·5014428	−10	−132	+10	−113	−132	−11	·5014157	·5014153	·5014155
" 18	4	3	D	I	173 42	174·12	5·9	1·7	18·26	54·50	·5014458	·5014399	−10	−136	+08	−151	− 93	−11	·5014158	·5014157	·5014158
" 18	5	3	D	I	173·10	173·83	5·5	1·9	18·78	56·60	·5014484	·5014415	−11	−154	+07	−152	− 89	−11	·5014163	·5014157	·5014160
" 18	6	3	D	I	173·64	172·87	5·3	1·5	18·71	57·55	·5014439	·5014503	−09	−155	+06	−113	−174	−11	·5014157	·5014160	·5014158
																Means			·5014158	·5014157	·5014158

GRAVITY

PENDULUM OBSERVATIONS AND REDUCTIONS — *Continued.*

Station WASHINGTON, D. C. *Observer* L. A. McDIARMID

Date	Swivel-bearder.	Pedestal.	Position.	Interchange.	Coincidence Interval — Chronometer No. 1823	Coincidence Interval — Chronometer No. 1841	Arc — Initial.	Arc — Final.	Temperature.	Pressure.	Period Uncorrected — Chronometer No. 1823	Period Uncorrected — Chronometer No. 1841	Corrections for 7th Decimal Place — Arc	Corrections for 7th Decimal Place — Temp	Corrections for 7th Decimal Place — Press	Rate — 1823	Rate — 1841	Elastic	Period Corrected — Chronometer No. 1823	Period Corrected — Chronometer No. 1841	Period Corrected — Mean
1914					s	s	turns.	turns.		mm.	s	s							s	s	s
May 6	1	2	D	1	157·52	158·08	6·0	2·0	18·48	49·20	·5015922	5015865	14	−146	11	+290	+224	−11	5015935	5015952	
" 6	2	2	D	1	157·91	158·19	5·3	1·8	17·96	56·60	·5015882	·5015854	10	−124	07	+290	+224	−11	5015971	5015940	
" 7	3	2	D	1	157·89	158·09	5·1	1·6	17·89	58·50	·5015884	5015865	08	−124	+06	+290	+224	−11	5015940	5015955	
																Mean			5015948	5015942	5015945
May 9	1	2	D	1	157·92	158·40	5·8	1·9	17·41	55·55	·5015881	5015[illegible]	14	101	+08	+294	222	−11	5015968	5015968	
" 9	2	2	D	1	158·06	158·[illegible]	5·6	1·7	17·54	59·85	5015857	5015845	10	−106	+01	+294	222	11	5015968	5015944	
" 10	3	2	D	1	158·20	158·22	5·4	1·5	17·41	64·05	5015844	5015851	09	88	−01	+294	+222	−11	5015939	5015964	
																Mean			5015948	5015849	5015948
																			Mean		5015946
May 7	1	1	D	1	176·59	177·42	5·1	1·7	17·96	51·75	5014213	5014151	−09	120	+11	488	+252	−11	5014272	5014254	
" 7	2	1	D	1	176·54	177·31	4·9	1·7	17·81	58·80	·5014201	5014137	09	−118	+09	488	252	11	5014260	5014254	
" 8	3	1	D	1	176·32	176·89	5·2	1·7	17·71	56·35	·5014219	5014175	−10	−114	+07	488	252	−11	5014279	5014297	
																Mean			5014270	5014270	5014270
May 10	1	1	D	1	177·11	177·22	5·7	1·8	17·04	54·80	·5014156	5014147	11	86	+08	+218	221	−11	5014274	5014268	
" 10	2	1	D	1	176·98	177·09	5·2	1·6	17·24	59·10	·5014166	5014164	09	−94	+04	+218	+221	−11	5014274	5014275	
" 11	3	1	D	1	176·84	176·78	5·4	1·6	17·34	63·45	·5014177	5014182	−10	−98	00	+278	+221	11	5014276	5014284	
																Mean			5014275	5014276	5014275
																			Mean		5014276

PENDULUM OBSERVATIONS AND REDUCTIONS (*Concluded*)

PENDULUM OBSERVATIONS AND REDUCTIONS (Concluded)

Station: OTTAWA, ONT. Observer: A. McDIARMID

Date.	Swings taken for	Pendulum	Position	Knife-edge	Coincidence Interval. Chronometer: Bond	Coincidence Interval. Chronometer: Riefler	Arc: Initial	Arc: Final	Temperature.	Pressure.	Period Uncorrected. Chronometer: Bond	Period Uncorrected. Chronometer: Riefler	Coefficients for Total Double Error. Rate: Arc	Rate: Temp.	Rate: Press.	Rate: B	Rate: E.	Rate: Error	Period Corrected. Chronometer: Bond	Period Corrected. Chronometer: Riefler	Mean
1914.					s.	s.	mm.	mm.	°	mm.	s.	s.							s.	s.	s.
May 18	1	1	D	I	188·77	190·32	6·0	2·0	18·46	51·60	·5013270	·5013470	·14	−·145	·11	·125	·15	·11	·5012995	·5012994	·5012994
" 18	2	1	D	I	188·34	189·97	5·7	1·6	19·06	56·95	·5013030	·5013195	·16	·170	−·07	−·02	·17	−·11	·5012995	·5012994	·5012994
" 19	3	1	D	I	188·26	189·84	5·9	1·8	19·16	62·15	·5013315	·5013204	−·12	−·174	−·08	·126	·17	−·11	·5012995	·5012992	·5012993
" 27	4	1	D	I	185·94	188·08	5·6	2·0	22·12	59·05	·5012484	·5012628	·12	·205	·05	·170	·14	·11	·5012995	·5012995	·5012995
" 27	5	1	D	I	186·85	188·55	5·5	1·8	21·31	62·90	·5013110	·5013294	·08	−·205	−·01	·130	·17	·11	·5012995	·5012993	·5012994
" 28	6	1	D	I	187·27	188·92	5·4	1·8	20·55	67·35	·5012885	·5013260	−·10	−·250	·00	−·145	·17	·11	·5012995	·5012994	·5012994
																Mean			·5012994	·5012994	·5012994
May 20	1	3	D	I	173·48	174·44	5·9	2·6	19·65	49·75	·5014486	·5014369	·16	·195	−·12	−·131	−·17	·11	·5014446	·5014445	·5014445
" 20	2	3	D	I	172·77	174·15	5·4	1·8	19·93	52·75	·5014516	·5014397	·08	·206	−·11	·128	·17	·11	·5014446	·5014464	·5014464
" 21	3	3	D	I	172·51	174·10	5·3	1·7	20·07	56·25	·5014534	·5014401	·10	−·213	−·08	·142	·17	·11	·5014467	·5014462	·5014462
" 24	4	3	D	I	172·90	174·46	5·5	1·7	19·65	53·25	·5014490	·5014471	·12	·195	−·11	·139	−·17	·11	·5014458	·5014447	·5014449
" 24	5	3	D	I	172·84	174·20	5·7	2·7	19·35	60·50	·5014506	·5014389	·16	·182	−·07	·142	·17	·11	·5014458	·5014466	·5014462
" 24	6	3	D	I	173·56	174·52	5·7	1·3	19·01	61·75	·5014446	·5014366	·09	·168	−·02	·136	−·17	·11	·5014459	·5014463	·5014461
" 29	7	3	D	I	171·60	173·34	5·6	1·7	21·64	55·50	·5014613	·5014465	−·11	·278	·00	·130	·17	·11	·5014455	·5014457	·5014456
" 29	8	3	D	I	171·22	173·11	5·7	1·8	21·94	58·50	·5014611	·5014483	−·12	·291	·00	·174	·17	·11	·5014461	·5014458	·5014460
																Mean			·5014457	·5014457	·5014457

PENDULUM OBSERVATIONS AND REDUCTIONS, 1904.

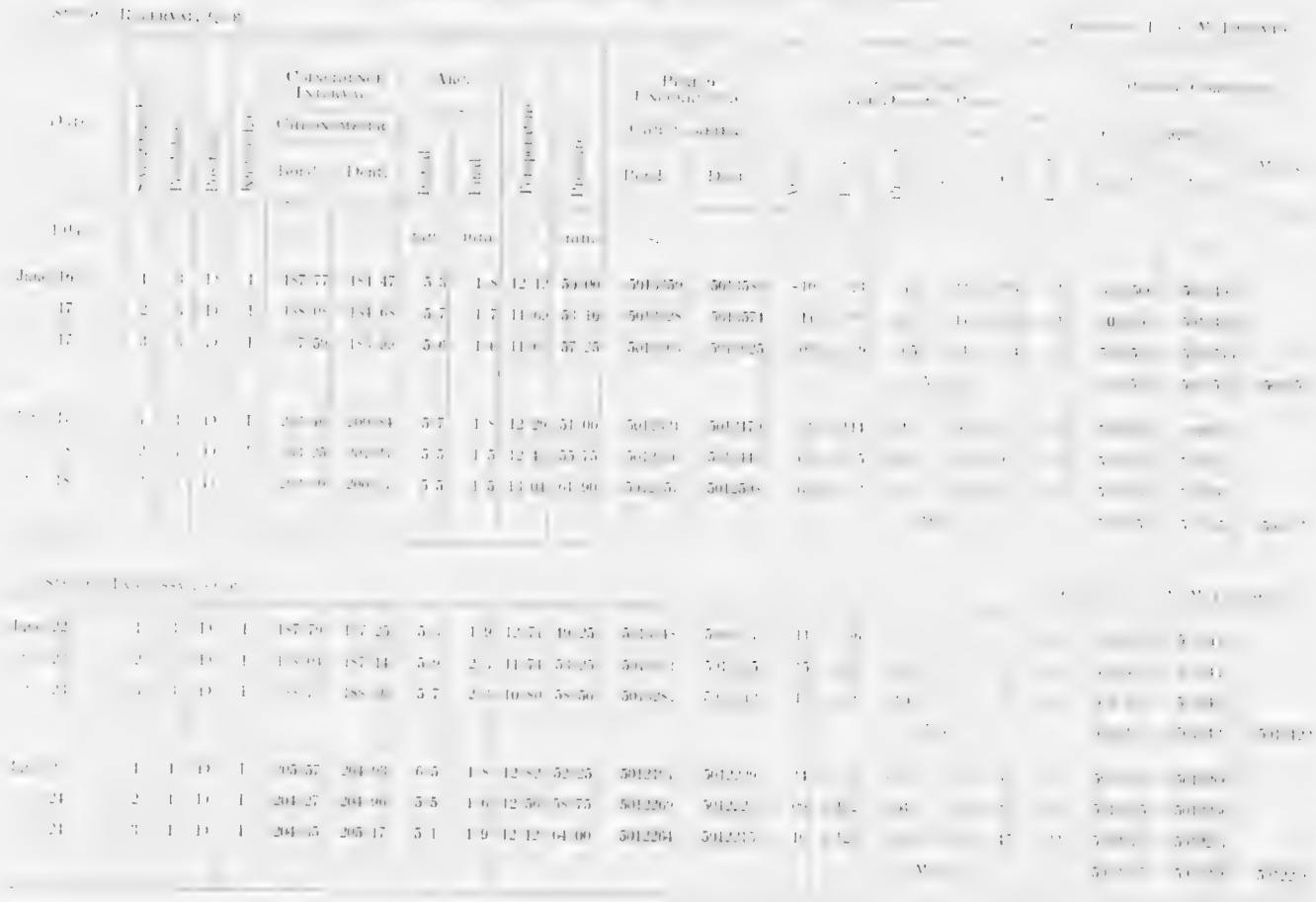
PENDULUM OBSERVATIONS AND REDUCTIONS (Concluded.)

Station MANOTAGAN, QUE. — Observer J. A. McDIARMID

Date	Swing number	Pendulum	Position	Knife-edge	Coincidence Interval. Chronometer: Bond	Coincidence Interval. Chronometer: Dent	Arc. Initial.	Arc. Final.	Temperature.	Pressure	Period Uncorrected. Chronometer: Bond	Period Uncorrected. Chronometer: Dent	Corrections for Decimals of Period. Rate	Corrections for Decimals of Period. Arc	Corrections for Decimals of Period. Pressure	Corrections for Decimals of Period. B	Corrections for Decimals of Period. G	Corrections for Decimals of Period. Temperature	Period Corrected. Chronometer: Bond	Period Corrected. Chronometer: Dent	Mean
1911.					s	s	mm	mm		mm											
June 1	1	3	D	I	178·93	178·51	5·5	1·7	12·39	50·75	·5014011	·5014044	·10	+·105	+·13	111	13	14	5013·99	5014029	
" 2	2	3	D	I	179·68	180·53	5·3	1·8	10·85	54·55	·5013951	·5013887	·10	+·174	−·08	111	11	14	5013999	5014062	
" 3	3	3	D	I	180·36	179·87	5·2	1·6	10·75	59·55	·5013909	·5013978	·09	+·178	−·01	111	12	4	5013·17	5013·84	
																	Mean		5013·981	5013·980	5013·980
June 3	1	1	D	I	196·98	194·59	5·1	1·7	10·85	50·75	5012724	5012881	·09	+·174	−·11	105	−·28	−·14	5012·81	5012·35	
" 3	2	1	D	I	196·18	194·51	5·7	1·9	10·75	53·30	5012779	5012836	·10	+·178	−·09	105	28	14	5012·84	5012·21	
" 4	3	1	D	I	196·39	194·86	5·2	1·1	10·80	57·50	·5012767	5012867	−·07	+·176	−·05	105	28	14	5012·817	5012·795	
																	Mean		5012·811	5012·810	5012·811

Station KINGSTON, ONT. — Observer J. A. McDIARMID

June 9	1	1	D	I	185·68	183·68	5·9	2·1	17·57	49·65	5013·500	5013·048	·13	·308	−·14	·185	·292	·11	5013·996	5013·257	
" 9	2	1	D	I	185·60	184·63	5·2	1·6	16·88	51·50	5013506	5013577	·09	·79	·11	·185	·292	·11	5013·206	5013·167	
" 10	3	1	D	I	186·14	184·74	5·5	1·6	16·25	54·75	5013466	5013569	·09	·52	·08	·185	·292	·11	5013·217	5013·214	
																	Means		5013·245	5013·210	5013·216
June 10	1	3	D	I	171·68	170·03	5·6	1·9	16·10	52·00	·5014605	·5014746	·12	·40	·11	·96	·284	·11	5014·81	5014·04	
" 10	2	3	D	I	171·72	170·58	5·7	1·7	15·97	55·85	·5014601	·5014699	·11	·41	·07	·96	·284	·11	5014·75	5014·50	
" 11	3	3	D	I	171·59	170·26	5·2	1·6	15·92	60·75	·5014612	·5014727	·09	·39	·02	·96	·284	·11	5014·89	5014·86	
																	Mean		5014·82	5014·84	5014·84



Station. PORTNEUF, QUE.

June 25	1	I	D	I	191 71	189 38	6 0	2·2	22 36	47 05	5013075	5013296	−14	−208	+17	139	271	11	5012920	5012940	
" 25	2	I	D	I	194 66	193 17	5·8	1·5	17 07	52 90	5012876	5012975	−10	−87	10	139	271	11	5012929	5012906	
" 26	3	I	D	I	195 37	193 83	5·2	2·5	16 05	59 50	5012832	5012931	−13	−44	+05	142	210	11	5012925	5012920	
																Mean			5012928	5012913	5012927
June 26	1	3	D	I	178 31	177 81	5·4	2·0	18 51	56 00	5014060	5014100	−11	−147	+08	102	151	11	5013790	5013788	
" 26	2	3	D	I	178 40	176 83	5·2	2·2	17 64	59 15	5014050	5014178	−12	−111	+05	111	235	11	5013788	5013754	
" 27	3	3	D	I	179 47	178 21	5·4	2·0	15 53	61 25	5013889	5014070	−11	−22	+02	−141	235	11	5013786	5013777	
																Mean			5013788	5013785	5013785

Station. ST. JEROME, QUE.

July 1	1	3	D	I	177 53	177 60	5 0	1·8	14 03	50 00	5014122	5014116	−09	+41	+12	165	146	11	5013980	5014001	
" 2	2	3	D	I	177 47	177 86	5 0	1·6	13 88	52 40	5014127	5014096	−08	−47	+10	165	146	11	5014009	5014088	
" 2	3	3	D	I	177 68	178 05	4·7	1·6	13 73	54 00	5014110	5014081	−08	+55	+09	171	143	11	5014002	5014096	
																Mean			5014004	5013995	5013964
July 2	1	1	D	I	193 62	194 68	6·1	2·0	13 58	48 75	5012945	5012875	14	59	+1	00	40	11	5012876	5012887	
" 3	2	1	D	I	193 05	196 51	6·4	1·9	14 03	51 30	5012941	5012755	15	+81	11	30	40	11	5012841	5012871	
3	3	1	D	I	193 55	196 28	5·5	2·5	13 15	54 50	5012950	5012769	14	+77	05	171	42	11	5012871	5012840	
																Mean			5012875	5012874	5012864

Station. STE. ANNE DE BELLEVUE, QUE.

July 8	1	1	D	I	188 75	187 74	5·5	2·3	20 13	46 25	5013280	5013552	15	−275	13	171	145	11	5013084	5013084	
" 8	2	1	D	I	188 95	187 24	5·5	2·0	20 17	48 50	5013268	5013488	12	−217	13	171	248	11	5013071	5013014	
" 9	3	1	D	I	188 59	188 07	5·4	1·6	20 20	52 65	5013291	5013528	09	−218	+11	171	248	11	5013089	5013056	
																Mean			5013082	5013084	5013087
July 9	1	1	D	I	173 84	172 36	6·1	2·1	20 35	52 00	5014423	5014547	14	221	+13	40	285	11	5014045	5014041	
" 9	2	1	D	I	175 09	172 04	5·5	1·9	20 38	54 00	5014439	5014574	12	225	+10	00	285	11	5014063	5014054	
" 10	3	1	D	I	174 81	172 56	5·0	1·7	20 37	57 0	5014342	5015530	−10	−225	+07	02	0	11	5014041	5013999	
																Mean			5014065	5014065	5014065

PENDULUM OBSERVATIONS AND REDUCTIONS (Concluded)

STATION: MAGNETIC, ONT.

Date	Coincidence Interval	Coincidence Uncertain	Coincidence Doubtful	Coincidence Lost	Coincidence Clock Numbers Entered	Coincidence Clock Numbers Deduced	Arc Entered	Arc Used	Pendulum Clock Numbers Entered	Pendulum Clock Numbers Deduced	Pendulum Uncertain	Pendulum Doubtful	Pendulum Lost	Clock Corrections Entered	Clock Corrections Deduced	Clock Rates Entered	Clock Rates Deduced	Pendulum Rates Entered	Pendulum Rates Deduced	Gravity
1914																				
July 14		3	D	1	175 26	174 40	5 4	1 8	17 47	19 85	501 05	500 800								
" 14			D	1	175 55	174 58	6 0	1 7	16 09	52 00	500 45	500 457								
" 15			D	1	175 08	175 02	5 4	1 6	16 5.	54 00	500 4 71	500 425								
July 15	1	1	D	1	186 70		5 6	4 5	16 87	48 25	500 42									
" 15	1	1	D	2	189 76	185 55	5 9	2 1	16 95	49 75	500 42	500 375								
" 15	1	1	D	1	186 92	185 01	5 6	1 6	16 96	51 25	500 417	500 340								
" 16	1	1	D	2	186 74	186 10	5 0	1 8	16 96	55 40	500 424	500 475								

STATION: LESKARD, ONT.

July 17	1	1	D	1	186 5	186 62	5 0	1 7	23 25	47 75	501 470	501 442								
" 18	2	1	D	1	187 75	187 90	5 4	1 0	21 40	54 00	501 53	501								
" 18	3	1	D	1	188 80	188 54	5 4	1 8	20 27	5. 85	501 571	501 505								
July 18	1	1	D	1	178 52	178 79	5 6	1 8	19 65	48 50	501 104	501 102								
" 19	2	1	D	1	178 62	180 45	5 2	1 8	18 65	51 50	501 000	501								
" 19	3	1	D	1	178 60	180 00	5 8	2 0	18 4.	55 75	500 90.	501 928								

Station COCHRANE, ONT. *Observer* F. A. McDIARMID

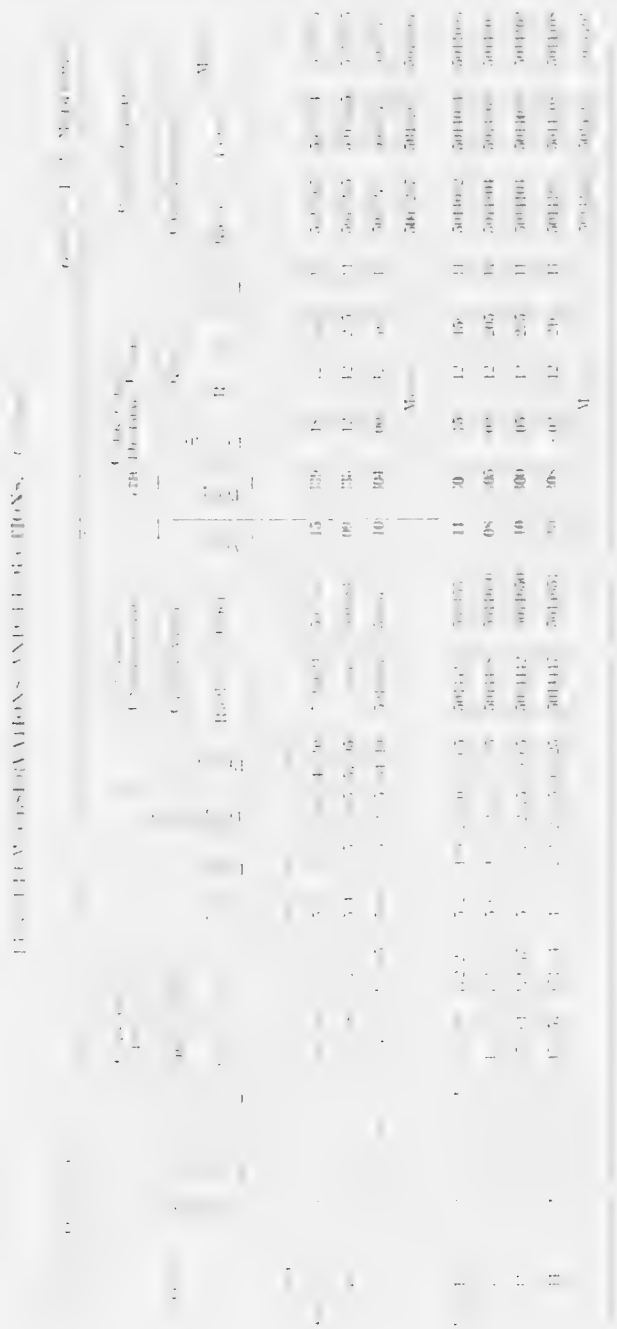
July	20	1	3	D	I	183·03	182·67	5·6	1·8	17 74	46 83	5013096	5013723	13	·115	·20	155	156	1	5	5013409	
"	21	2	3	D	I	183·11	184·03	5·4	1·9	17·24	51 75	5013690	5013622	−11	94	·21	·55	156	11	5	5013681	
"	21	3	3	D	I	183·25	183·85	5·9	1·8	17·14	55 40	5013680	5013655	−12	·90	·08	−150	−109	−11	5	5013425	5013421	
																	Mean				5013475	5013552	5013424
July	21	1	1	D	I	195 24	194 76	5·6	1·9	17 17	52 00	5012838	5012869	−12	·91	·17	15	156	11	5	5013578	5013604	
"	22	2	1	D	I	194·85	195·08	6·0	1·8	17·34	61·00	5012866	5012848	−13	·98	·19	15	152	11	5	5013501	5013576	
"	23	3	1	D	I	194·16	194·67	4·9	1·6	18·05	55·00	5012908	5012875	−08	·128	·08	157	143	11	5	5013550	5013595	
																	Mean				5013543	5013579	5013586

Station SAULT STE MARIE, ONT. *Observer* F. A. McDIARMID

July	24	1	1	D	I	185 78	186·07	5·7	1·8	19·70	55·30	5015493	5015472	14	·197	·06	172	177	11	5	5015511	5015487	
"	25	2	1	D	I	186·42	185·99	6·1	1·9	18·66	55 40	5015447	5015478	14	15	·08	172	177	11	5	5015479	5015462	
"	25	3	1	D	I	186·31	187 76	5·9	2·0	18 29	58 75	5015455	5015450	−13	·155	·05	−195	− 99	−11	5	5015304	5015315	
																	Mean				5015465	5015488	5015410
"	25	1	3	D	I	175 88	175 88	5·8	2·0	18 21	50 60	5014255	5014255	1	131	·04	265	15	11	5	5014545	5014547	
"	26	2	3	D	I	175·84	176·93	5·7	1·5	18·06	63·09	5014258	5014170	09	127	·06	·5	5	11	5	5014145	5014	
"	26	3	3	D	I	175·84	176·58	5·2	3·3	17 96	53 70	5014282	5014198	16	124	+09	−189	− 79	−11	5	5013951	5014	
"	26	4	3	D	I	175 61	177 12	2 81	1·6	18 19	74 38	5014277	5014155	04	1	·05	·5	5	11	5	5014	5014	
																	Mean				5014	5014	5014

STATION.—CHAPPAQUA, ONT.

Date	Clock	Pendulum	Receiver	Coincidence Interval Chronometer Observed	Coincidence Interval Chronometer Deduced	Arc Initial	Arc Final	Time of Vibration		Chronometer Rate Observed	Chronometer Rate Deduced	Chronometer Correction Observed	Chronometer Correction Deduced	Local Time Observed	Local Time Deduced	Gravity
1906				h. m. s.	h. m. s.	ins.	ins.	s.		s.	s.	s.	s.	h. m. s.	h. m. s.	
July 28	1	1	D	1	178 56	178 46	4 7	3 8	0	58 5	59					
" 28	1	1	D	1	178 50	179 25	3 6	1 8	15	0	58					
" 28	1	1	D	1	178	180 51	5 5	1 6	15	58	59					
" 29	1	1	D	1	179 58	181 46	5	2	14	59	59					
Aug. 1	1	1	D	1	191 06	192 07	5 5	1 7	15	59	59					
" 1	2	1	D	1	191 46	192 25	6 1	1 7	14	59	59					
" 1	1	1	D	1	191	192	5	1 9	14	59	59					
Aug. 30	1	1	D	1	181 74	181 06	5	2 1	15	59	59					
" 31	2	1	D	1	181 80	180 95	5	1 8	15	59	59					
" 31	1	1	D	2	182	181	5	1 9	15	59	59					



G—26018

PENDULUM OBSERVATIONS AND REDUCTIONS (Concluded)

Station: Ottawa, Ont. — Observer: A. McLean Howe

Date	Swing number.	Pendulum.	Position.	Knife-edge.	Coincidence Interval — Chronometer: Riefler	Coincidence Interval — Chronometer: Bond	Arc: Initial.	Arc: Final.	Temperature.	Pressure.	Period Uncorrected — Chronometer: Riefler.	Period Uncorrected — Chronometer: Bond.	Corrections (7th Decimal Place) — Arc.	Corrections (7th Decimal Place) — Temp.	Corrections (7th Decimal Place) — Pressure.	Rate: R	Rate: B	Hourly.	Period Corrected — Chronometer: Riefler.	Period Corrected — Chronometer: Bond.	Mean.
1914					s.		mm.	mm.	°	mm.	s.									s.	
Sept. 8	1	3	D	I	174·96	173·65	5·5	2·1	20·22	45·00	5014332	·5014479	12	−240	+18	·98	1·15	11	5014102	5014100	5014101
" 8	2	3	D	I	175·12	173·66	5·9	2·0	19·75	52·20	5014317	·5014458	14	−199	+11	·96	1·23	11	5014099	5014103	5014101
" 9	3	3	D	I	175·27	174·17	5·7	1·8	19·38	60·90	5014305	·5014495	12	−185	+0	·96	1·30	11	5014097	5014102	5014100
																Mean			5014099	5014102	5014101
" 9	1	1	D	I	186·99	186·37	5·9	2·6	19·40	46·00	5013406	·5013450	15	−184	−16	·99	·51	11	5013206	5013205	5013206
" 9	2	1	D	I	187·14	186·36	5·9	1·9	18·90	55·20	5013395	·5013455	17	−163	−09	·96	·62	11	5013211	5013211	5013211
" 10	3	1	D	I	186·92	186·43	5·8	1·7	19·20	65·20	5013411	·5013446	11	−176	01	·96	·39	11	5013206	5013208	5013207
																Mean			5013208	5013208	5013208

DEDUCTION OF ABSOLUTE GRAVITY.

The ratio of gravity at two places is readily obtained from fundamental formula of the simple pendulum, $P = \pi \sqrt{\frac{l}{g}}$, where P is the period and l is the length of the corresponding pendulum, and g is the force of gravity. We have then the relation, $P^2 : P_s^2 = g_s : g$, or $g = \frac{P_s^2}{P^2} \cdot g_s$, where P_s and g_s are the period and gravity at the base station and P is the period at the field station.

The observed value of gravity at Washington is taken as 980·112 dynes. Adopting this value, and using the values of the periods of pendulums 1 and 3 for Washington and Ottawa, the values of gravity for Ottawa are 980·618, 980·613, 980·616 and 980·615 dynes, or the mean value of gravity at Ottawa is 980·615 dynes which has been adopted as the observed value for Ottawa

All the field stations have been referred to Ottawa. In deducing the gravity for the different stations three different sets of values for the pendulums at Ottawa were used. The change in periods has already been referred to in the discussion of "Variation in lengths of pendulums." For the stations, Maniwaki, Kingston, Roberval, Tadoussac, Portneuf, St. Jérôme, and Ste. Anne-de-Bellevue, the periods of the pendulums obtained at Ottawa in May were used; for the stations, Mattawa, Liskeard, Cochrane, Sault Ste. Marie, Chapleau, Port Arthur and Rose Point, the periods obtained in August were used; and for Whitby, Woodstock and Windsor, the periods obtained in September were used.

COMPUTATION OF THE INTENSITY OF GRAVITY AT ANY SELECTED STATION.

The intensity of gravity may be computed on an ideal earth having the same size and shape as an ellipsoid of revolution which most nearly coincides with the sea-level surface of the real earth, and having no topography and no variations in density at any depth. To convert the real earth into this ideal earth all material on the real earth above sea-level must be removed, the water of the ocean must be replaced by material of density equal to the mean surface density of the real earth, and all

variations in density at any given depth in the real earth must then be removed by taking out or rejecting enough material in each part to make the density conform accurately to the mean density in the real earth at that point. In this ideal earth the density will increase with increase of depth in the same manner as it does upon an average in the real earth, but in the ideal earth all masses lying at the same depth will have the same density, whereas in the real earth such masses have densities which are known to differ slightly from one another.

Using Helmert's formula $\gamma_o = 978{\cdot}030\ (1 + 0{\cdot}005302 \sin^2 \varphi - 0{\cdot}000007 \sin^2 2\varphi)$, where γ_o = required gravity at a station on the ideal earth above described in the latitude φ. On such an ideal earth the value of gravity at the surface would be a function of the latitude only. The numerical value of γ_o is both the acceleration in centimetres per second per second, and the attraction in dynes on a unit mass (1 gram) at the station expressed in the centimetre-gram-second system.

The formula is thus fixed by theory. The three constants 978·030, 0·005302 and 0·000007 were derived from a great number of observations scattered over the surface of the earth. New and better values of these constants will no doubt be obtained from more observations. Up to the present time there have only been the few observations for gravity already referred to taken in Canada, and so the observed value of gravity at many stations scattered over the northern half of this continent should give information that will be of great value in determining the correct equation for gravity.

In computing the intensity of gravity in the United States, Helmert's formula was used; and from the observations there a small correction to the constant 978·030 was made. It became 978·038.

CORRECTIONS FOR ELEVATION, TOPOGRAPHY, AND ISOSTATIC COMPENSATION.

Elevation.—The correction for elevation was computed by the formula $-0{\cdot}0003086\,H$, in which H is the elevation of the station above sea-level in metres. This correction of the attraction upon a unit mass (1 gram)

at the station is in dynes and reduces from sea-level to the actual station. It takes account of the increased distance from the attracting mass, as if the station were in the air at the stated elevation and there were no topography on the earth.

Topography and Isostatic Compensation.—The stations at which observations are made are on the real earth, and are in general above sea-level. The second part of the computation of the intensity of gravity at any station must therefore take account of the topography which exists on the earth, take account as far as possible of the variations in density which exist on the real earth, and take account as far as possible of the variation in density beneath the surface of the true earth, and take account of the elevation of the observing station above sea-level.

To apply the corrections for topography and isostatic compensation, accurate topographical maps are required, at the present time there are no such maps of Canada, hence the discussion of these corrections will be treated in a later report. Messrs. Hayford and Bowie have discussed the whole matter very fully in their publication "The Effect of Topography and Isostatic Compensation upon the Intensity of Gravity."

However, there are other methods of reducing the value of the force of gravity from sea-level to the observing station. These are known as the "free-air" method, Bouguer's method and Faye's method. The free-air method takes account only of the elevation above sea-level. The station is considered as if it were suspended in the air at a height equal to the elevation. In Bouguer's formula $dg = -\frac{2g \cdot H}{r}\left(1 - \frac{3}{4}\frac{\delta}{\Delta}\right)$, on the supposition that the station is situated on an indefinitely extended plain. Here dg is the correction to computed gravity, g, at sea-level, H is the elevation above sea-level, r is the radius of the earth, δ is the density of the matter lying above sea-level, and Δ is the mean density of the earth. The Bouguer method takes no account of the isostatic compensation and neglects all curvature of the sea-level surface, the topography being treated as if it were standing on a plain of indefinite extent. The results from applying these two methods seem to lead to the conclusion that general continental

elevations are compensated by a deficiency of density in the matter below sea-level, but that local topographical irregularities, whether elevations or depressions, are not compensated for, such irregularities being maintained by the partial rigidity of the earth's crust.

The residuals with Bouguer's reduction should then be interpreted as a measure of the deficiency of density, and on the other hand, the residuals with the reduction for elevation should be taken as a measure of the lack of compensation, after allowing for uncertainties of observation and the effects of local geological conditions. Developing the idea of M. Faye, observed values of g may be corrected for this lack of compensation by adding or subtracting the vertical attraction of a horizontal plain whose thickness is the difference in elevation between the station and the average surrounding surface. This correction may be expressed by $dg = 2g \cdot \frac{h}{r} \cdot \frac{3}{4} \frac{\delta}{\Delta}$, which represents the attraction of an indefinitely extended horizontal plain of thickness h and density δ. The correction is positive for stations below the average level and negative for stations above the average level. The average elevation may be secured from a contour map for the country within a radius of one hundred miles.

In the following Table I will be given the values for the periods of the pendulums at the different stations, and the deduced value of gravity in dynes. In Table II will be applied the corrections for elevation and topography according to the three different methods outlined above. In Table III will be found a comparison between the gravity obtained for Ottawa in 1902 and in 1914. The difference of ·014 dynes is probably due in part to the situation of the two stations. The 1902 station was near the bank of the Ottawa river; the bank at this point rising about one hundred feet from the water in an almost perpendicular direction. The 1914 station is distant from the river about one and a half miles, and the country around the station is fairly level.

TABLE I

Station	Period of Pendulum.		Value of g in Dynes.		
	1	3	1	3	Mean
Washington	·5014261	·5015449			980·112
Ottawa	·5012669	·5014160	980·618	980·616	
Washington	·5014275	·5015445			
Ottawa	·5012995	·5014157	980·643	980·645	980·645
Manowaki	·5012841	·5013980	980·686	980·684	980·685
Ingleton	·5013216	·5014583	980·528	980·526	980·527
Robeval	·5012357	·5013512	980·863	980·867	980·865
Tadoussac	5012266	·5013422	980·900	980·903	980·901
Portneuf	·5012627	·5013785	980·759	980·761	980·760
St. Jérôme	·5012834	·5013993	980·677	980·679	980·678
Ste. Anne-de-Bellevue	·5012883	·5014035	980·657	980·663	980·660
Ottawa	·5013267	·5014101			980·645
Mattawa	5013182	5014022	980·647	980·646	980·647
Liskeard	·5012831	·5013666	980·785	980·785	980·785
Cochrane	·5012589	·5013424	980·880	980·880	980·880
Sault Ste. Marie	·5013107	·5013942	980·677	980·677	980·677
Chapleau	·5012884	·5013727	980·761	980·762	980·763
Port Arthur	·5012747	·5013587	980·848	980·846	980·847
Rose Point	·5013202	·5014140	980·605	980·600	980·603
Ottawa	·5013208	·5014101			980·645
Whitby	·5013615	·5014193	980·455	980·461	980·458
Woodstock	·5013891	·5014778	980·348	980·350	980·349
Windsor	·5013920	·5014806	980·337	980·340	980·338

TABLE II.

Station	Longitude	Latitude	Altitude	Computed g at sea-level	Corrections			Observed Gravity	Anomalies		
					Free-air	Bouguer	Faye		Free-air	Bouguer	Faye
	h. m. s.	° ′ ″	metres	dynes.	dynes.	dynes.	dynes.	dynes.	dynes.	dynes.	dynes.
Ottawa	5 02 52	45 23 39	83	980·651	−·026	−·016	−·033	980·615	−·010	−·020	−·003
Maniwaki	5 05 55	46 22 28	169	980·749	−·052	−·033	−·058	980·685	−·003	−·022	+·003
Kingston	5 05 52	44 14 37	79	980·547	−·024	−·015	−·024	980·527	+·004	−·005	+·004
Roberval	4 48 54	48 30 54	107	980·933	−·033	−·021	−·065	980·865	−·035	−·047	−·003
Tadoussac	4 38 52	48 08 25	12	980·960	−·004	−·002	+·027	980·901	+·005	+·003	−·026
Portneuf	4 47 35	46 42 32	59	980·770	−·018	−·011	−·014	980·760	+·008	+·001	+·004
St. Jérôme	4 52 28	45 46 34	107	980·686	−·033	−·021	−·033	980·678	+·025	+·013	+·025
Ste. Anne-de-Bellevue	4 55 48	45 24 27	34	980·653	−·010	−·006	−·012	980·660	+·017	+·013	+·019
Mattawa	5 14 47	46 18 43	170	980·734	−·052	−·033	−·009	980·647	−·035	−·054	−·018
Liskeard	5 18 50	47 30 34	194	980·843	−·060	−·037	−·063	980·785	+·002	−·021	+·005
Cochrane	5 24 05	49 03 44	277	980·983	−·085	−·053	−·089	980·880	−·018	−·050	−·014
Sault Ste. Marie	5 37 18	46 30 26	186	980·752	−·057	−·036	−·067	980·677	−·018	−·039	−·008
Chapleau	5 33 36	47 50 27	430	980·872	−·133	−·083	−·126	980·763	+·024	−·026	+·017
Port Arthur	5 56 52	48 26 00	189	980·926	−·058	−·036	−·074	980·817	−·051	−·073	−·035
Rose Point	5 20 10	45 19 02	183	980·644	−·056	−·035	−·052	980·603	+·015	−·006	+·011
Whitby	5 15 46	43 52 43	84	980·514	−·026	−·016	−·030	980·458	−·030	−·040	−·026
Woodstock	5 23 07	43 08 33	299	980·448	−·093	−·060	−·093	980·349	−·006	−·039	−·006
Windsor	5 32 10	42 19 16	178	980·373	−·055	−·034	−·051	980·338	+·020	−·001	+·016
							Indiscriminate mean		·018	·027	·014
							Algebraic mean		−·005	−·022	−·002

TABLE III.

COMPARISON OF OBSERVED GRAVITY, OTTAWA, 1902 AND 1914.

Station	Latitude	Diff. of Latitude	Altitude	Diff. of Altitude	Observed Gravity	1902 Station to 1914 Station: Corrections for		Gravity at 1914 Station
						Latitude	Altitude	
	° ′ ″	′ ″	metres	metres	dynes	dynes	dynes	dynes
Ottawa (1902)	45 25 23	1 44	73	.....	980·607	−·003	−·003	980·601
Ottawa (1914)	45 23 39	.....	83	10	980·615	.....	.....	980·615
							Difference	·014

REASONS FOR THE PROSECUTION OF PENDULUM WORK*

"(1) The first scientific object of a geodetic survey is the determination of the earth's figure. It is probable that pendulum experiments afford the best method of determining the amount of oblateness of the spheroid of the earth, for the calculated probable error in the determination of the quantity in question from pendulum observations does not exceed that of the best determination from triangulation and latitude observations. Besides, the measurement of astronomic ares upon the surface of the earth cover only limited districts, and the oblateness deduced from them is necessarily affected. On the other hand, the pendulum determinations are subject to no great errors which least-squares cannot ascertain; they may be widely scattered over the earth they may be very numerous, they are combined to obtain the ellipticity by a simple arithmetical process; and the calculated probable error deduced from them is worthy of unusual confidence. It is very significant that while the value derived from pendulum work has remained nearly constant, that derived from measurements of arc has been continually changing as more data has been secured, and the change has been in the direction to accord with the pendulum method. Also, the expense of the pendulum method is small compared with the geodetic method.

"(2.) Investigation has shown the importance of pendulum experiments to metrology.

"(3.) Geologists affirm that from the values of gravity at different points, useful inference can be drawn in regard to the geological formation of the underlying strata.

"(4.) Gravity is extensively employed as a unit in the measurement of forces. Thus, the pressure of the atmosphere is, in the barometer, balanced against the weight of a measured column of mercury; the mechanical equivalent of heat is measured in foot-pounds, etc. All such measurements refer to a standard which is different in different localities, and it is therefore very important to determine the amounts of these differences as the exactitude of measurement is improved.

"(5) It is hoped that as the knowledge of the constitution of the earth's crust becomes, by the aid of pendulum experiments, more perfected we shall be able to establish methods by which we can with confidence infer

*United States C. & G. S. report 1882, Appendix No. 22.

from the vertical attraction of mountains, etc., what their horizontal attraction, and the resulting deflection of the plumb line must be.

"(6.) Although in laying out the plan of a geodetic survey the relative utility of the knowledge of different quantities ought to be taken into account, and such account must be favourable to pendulum work, yet it is true that nothing appertaining to such a survey ought to be neglected. The knowledge of the force of gravity is not a mere matter of utility alone, it is also one of the fundamental kinds of quantity which it is the duty of a geophysical survey to measure. Astronomical longitudes and latitudes are determinations of the direction of gravity; pendulum experiments determine its amount. The force of gravity is related in the same way to the latitude and longitude as the intensity of magnetic force is related to the magnetic declination and inclination, and, as a magnetic survey would be held to be imperfect in which measurements of intensity were omitted, to the same extent must a geodetic survey be held to be imperfect in which the determinations of gravity have been omitted."

These reasons for the prosecution of pendulum determinations were given by Mr. C. S. Pierce before a conference on gravity determinations held in Washington in May, 1882. This conference was attended by the Superintendent of the United States Coast and Geodetic Survey, Major Herschel, R.E., Prof. C. S. Pierce, Prof. Newcomb, and Messrs. George Davidson and C. A. Schott. But what was true in 1882 applies with equal force in 1914, and especially in a country such as Canada where a geodetic survey is only in its infancy.

CONCLUSION.

In concluding this report the writer desires to express his gratitude for assistance which he has received from Mr. William Bowie, Chief of the Computing Division of the United States Coast and Geodetic Survey, from Mr. W. H. Burger in his article on "The Measurement of the Flexure of pendulum supports with the Interferometer", and from Dr. W. F. King, Chief Astronomer, who gave many valuable suggestions.

Dominion Observatory,
Ottawa,
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